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A Summary of the Symposium on Interstellar Lines at the Yerkes Observatory, on June 30, 1941

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In many fields of modern science it is useful to bring together from time to time specialists who are interested in a definite problem and who are able to discuss it from different angles. This is evidenced by the remarkable results of some recent astrophysical conferences in which practical and theoretical astronomers met with a number of physicists. A striking example is the one-day conference on interstellar lines which took place at the Yerkes Observatory on June 30, 1941, at the suggestion of Dr. O. Struve. Besides the Yerkes Observatory group, about twenty physicists actively took part in the symposium, especially Dr. R. S. Mulliken (Chicago), Dr. E. Teller (Washington), Dr. G. Herzberg (Saskatchewan), Dr. H. Beutler (Chicago), and Dr. C. A. Rieke (Chicago). The present report is a summary of the discussions and of the remarkably quick and important results which followed.

I. Dr. O. Struve opened the symposium by giving a general account of the present status of the problem of interstellar atomic lines. The evidence for the existence of interstellar gaseous matter results from the observation of sharp stationary absorption lines in the spectra of stars with variable radial velocities. This interpretation is supported by the fact that their intensities generally increase with the distance of the star and by the discovery of emission lines of *H* and [*O*II] in vast areas of the Milky Way. The first two columns of Table 1 contain the atomic lines heretofore observed and identified. In the third column are tabulated some ultimate lines which may be observed in the future.

TABLE 1

Absorption lines	Emission lines	Not yet found, but likely
NaI D_1 5896 D_1' 3303 D_2 5890 D_2' 3302	H_α, H_β, H_γ;	AlI 3944.01;
KI 7698.98	[*O*II] 3727;	ScII 3642.80;
CaI 4226.73	[*O*III] N_1, N_2;	SrII 4077.73, 4215.54;
CaII H and K	[NII] 6548; 6584.	BaII 4554.04, 4934.09.
TiII 3242; 3384; 3229; 3073.		
FeI 3719.95 ?		

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Once the existence of the interstellar matter has been established and the elements identified, many interesting questions arise as to the density of this matter, the relative abundances of the elements, and the physical conditions which prevail in interstellar space. It is clear that the answers to these questions are not independent. One of the determining factors as to the physical conditions is the radiation of the stars. But before reaching a given point P in the interstellar space it is obvious that the stellar radiation undergoes an absorption which depends upon the density of the interstellar matter, its composition and the type of aggregates which it forms. As usual in physical science, this problem has been solved by successive approximations. For stars radiating like black bodies, the most complete study of this problem has been carried out by Dunham. It consists in evaluating, by extrapolation of the conditions observed from the earth and by taking into account the general interstellar absorption, the number of quanta of frequency ν present in a cubic centimeter at the point P considered. For many problems, such as those of ionization and dissociation, it is then convenient to resolve this actual distribution of radiative energy into a certain number of black-body curves of different temperature T_n, which are affected by factors of dilution δ_n. In interstellar space, because of the very low density (dynamical considerations yield an upper limit of the order of 3.10^{-24} gr./cm^3) the main process of transformation of radiative energy into kinetic energy is provided by the ionization of the atoms. Electrons liberated by black-body radiation of temperature T_n will have a temperature αT_n where α is somewhere between $\frac{1}{3}$ and $\frac{2}{3}$. If they are liberated simultaneously by radiations of different temperatures T_n, they will level off their mean kinetic energies by collisions and take a mean temperature T^o in which the higher αT_n will be favored. An accurate evaluation of T^o is not so important because the determining factor in the problems which we shall have to consider is always the radiative temperature. The first of these problems is that of the ionization in interstellar space. In presence of black-body radiation of temperature T_n diluted by a factor δ_n a number of theoretical investigations have shown that the numbers of atoms M_r and M_{r+1} in the r^{th} and $(r+1)^{th}$ states of ionization of statistical weights u_r and u_{r+1} are related by the equation

$$\log\,(M_{r+1}/M_r)_n = -5040X_r/T_n + 3/2\log T_n + \log\,(2u_{r+1}/u_r) - \log N_e + 1/2\log\,(T^o/T_n) + \log\delta_n + 15.38, \quad (1)$$

where X_r is the ionization potential of the atom in the r^{th} state and N_e is the electronic density. For a composite radiation, such as that considered previously, we have

$$(M_{r+1}/M_r) = \sum_n (M_{r+1}/M_r)_n \quad (2)$$

However, in establishing these formulae two aspects of the problem have been neglected. First of all, the ionization always takes place from the ground state of the atoms while the recombination can happen to any

of the excited states. If a_g and a_t represent the recombination coefficients toward the ground state and toward the totality of the states (normal and excited) we have to multiply M_{r+1}/M_r by a_g/a_t (Bates, Massey). On the other hand, when traveling through space, the radiation not only undergoes a general absorption and dilution but a part of it is used to maintain the equilibrium of ionization all along its path. For a very abundant element this can lead to important and interesting effects which have been worked out in detail by B. Strömgren.

To derive the abundance of an element from the observed intensity of one of its absorption lines, we must know the oscillator strength f of the line, the curve of growth for interstellar space (or a region of it) and the electron density, so that by equation (1) we could compute the fraction of atoms in the state considered. In the early investigations of this problem, one had simply supposed that the intensity of the line was proportional to $M_x f$ if M_x is the number of atoms in the state considered, and one had adopted a very low value of the electron density $N_e \sim 10^{-3}/cm^3$. This led to an abundance of *Na* in interstellar space equal to some 300 times the corresponding abundance of *Ca*, while on the earth and in the stellar atmospheres they are of the same order. Eddington questioned the first of these assumptions and applied considerations previously developed by Struve, Elvey, and Unsöld in order to show that the differential galactic rotation could remove this difficulty by bringing the points representative of the lines of *Ca*II and *Na*I on the flattest part of the curve of growth. But if this theory were correct, important effects of distance and longitude would appear which have never been observed. Furthermore, an investigation by O. C. Wilson and P. W. Merrill has shown that there are many nearby stars for which the ratio of the intensities of the lines of the doublet D of *Na* is approximately equal to 2 and, since $f_2/f_1 = 2$, this proves that, at least for these stars, the intensities of the lines vary as $(M \cdot f)$. On the other hand, recent observations by Dunham of lines of *Ca*I, *Ti*II, and *K*I have shown that the degree of ionization in interstellar space must be much lower than previously assumed. All this suggested that the value of N_e adopted was too low. To settle this point, good observational curves of growth and observations of the intensities of lines of the same atom in two different states of ionization were needed. The curves of growth can be derived from the observations of the ratio of the intensities of the components of the D lines of *Na* in stars at different distances (Wilson and Merrill) or of the observations of the intensities of the D and D′ lines of *Na* in the same star (Dunham).

Using the intensities of the lines of *Ca*I and *Ca*II given by Dunham and the curve of growth of Wilson and Merrill, O. Struve by application of equation (1) found $N_e = 30$ el./cm³. Using his own curve of growth, Dunham found $N_e = 14.4$ el./cm³ if one neglects the general absorption, and $N_e = 7.3$ el./cm³ if one takes it into account. If one considers these values of N_e as reliable it is now very easy to determine

the abundances of the different atoms of which we observe lines. The results of this determination are shown in Table 2. One can see, in particular, that the ratio *Na/Ca* is now reduced to 10, instead of 300. If one takes into account the Bates-Massey correction for *Ca*, one obtains $N_e = 2.7$ el./cm³. But this would not increase the ratio *Na/Ca* since according to Strömgren the Bates-Massey correction would still be greater for *Na* than for *Ca*. To account for the large electron density obtained in this way, it was natural to think of hydrogen and one can see from Table 2 that an abundance of *H* in good agreement with other astrophysical evidence is required for this purpose.

TABLE 2

	Log. N/cm³			
Element	O. Struve	Dunham	Sun	Nebulae
Electrons	0.2	1		
Hydrogen	0.2	1	0	0
Oxygen	—3		—1.5	—2
Sodium	—6	—4	—3.3	—4
Potassium		—5	—3.7	—5
Calcium	—7	—5	—3.8	—4
Titanium		—7	—5.3	—4
CH		—6		
CN		—6		

Because of the great relative abundance of *H*, the correction of Strömgren, referred to previously, will be important. To take it into account we have to multiply the values of M_{II}^+/M_{II} by a factor τ_ν where

$$\tau_\nu = \int_0^s \sigma_\nu M_{II}\, ds$$

where σ_ν is the coefficient of absorption per atom, of radiation of frequency greater than the limit ν_L of the Lyman series, and s is the distance traveled by the radiation from the hot star or group of hot stars considered to the point P where we study the ionization of *H*. Because of this exponential factor, the regions where *H* is ionized will be rather sharply limited, the outside regions containing no quanta of ν greater than ν_L. In the H^+ regions the Balmer lines will appear in emission.

The identification of these regions with the bright regions with emissions lines of *H* and [*O* II] discovered by Struve and Elvey is well supported by the facts that these regions are particularly rich in hot *O*-stars and that their radius is of the same order as computed from the theory of Strömgren. Furthermore, from the observed intensities of the emission lines of *H*, it is possible to compute M_{II}, and Strömgren found $M_{II} = 3$/cm³, which is in very good agreement with the values of N_e and M_{II} derived previously from *Ca* I/*Ca* II, when one takes the Bates-Massey correction into account.

Struve showed that the presence of the emission lines of [*O* II] in the same regions and of [*O* III] in their central parts also agrees with Strömgren's theory. Struve also explained why one does not observe

emission lines of *Na*I and *Ca*II, or absorption lines of *H*. The abundance of *O* given in Table 2 has been derived from the intensity of the emission line λ 3727 of [*O*II].

Moreover, as a result of Strömgren's theory, N_e outside the regions where *H* is ionized will be very low—in fact of the order of 10^{-3}/cm³ which had been adopted previously. Since this is incompatible with the intensities of the observed absorption lines, we must conclude that these lines originate mainly in the regions of H^+.

Finally, certain observations of interstellar lines indicate that interstellar space is far from being homogeneous from the point of view of the repartition of matter as well as from the point of view of the distribution of the physical conditions, and one of the most urgent tasks is the study of this heterogeneity. We can also remark that we have always supposed that the stars radiate like black bodies and that the more direct determination of N_e rests on the ratio of the intensities of the lines of *Ca*I and *Ca*II, the first being very weak and difficult to measure.

II. Dr. P. Swings then discussed the lines of molecular origin. We have already been accustomed by the observed atomic lines to consider that the excitation in interstellar space is very low; for instance, we observe only lines originating from the ground level $^4F_{3/2}$ of Ti^+, although the excitation potential of $^4F_{5/2}$ is only of the order of 0.012 volt. This explains why the only features definitely attributed to molecules are sharp lines, although the first reference to interstellar molecules was made by Russell in 1935 in trying to identify several rather diffuse lines discovered by Merrill.

Swings and Rosenfeld in 1937 tentatively identified λ 4300.3 as being due to *CH* ($A^2\Delta \leftarrow X^2\Pi$). This was strongly confirmed in June, 1940, when Adams found in the spectrum of ζ Ophiuchi, λλ3886.32, 3878.7, and 3890.15 [transitions (0.0) in the electronic system $^2\Sigma \leftarrow {}^2\Pi$ of *CH*, starting from the lowest rotational level]. Other sharp molecular lines have been identified, namely R(0) and R(1) in the transition (0.0) of

TABLE 3

Characteristics	λ	ν (cm^{-1})	$\Delta\nu$	Remarks
Sharp lines	4232.58	23619.6		
			1640.3	
	3957.72	25259.9		According to Adams these three lines are connected.
			1432.5	
	3745.33	26692.4		McKellar suggested that this is R(0) of (9,0) in $^1\Sigma \leftarrow {}^1\Sigma$, NaH.
	3579.04	27932.5		
	3934.3	25410.3		
Broad lines (width ~ 3A)	5780.55			
	5797.13			Band of solid *O* at λ 5796
	6202.99			
	6269.99			
	6283.91			
	6613.9			
Very broad line (width ~ 40A)	4427	22582		

CN ($^2\Sigma \leftarrow {}^2\Sigma$) at λλ 3874.61 and 3874.02 (the difference in rotational energy is only of the order of 0.00042 volt). One can also expect to find λ3357.8 of NH and λ3078.4 of OH. The interstellar lines which are still unidentified are given in Table 3.

We may be certain that the sharp features are not atomic lines. On the other hand, none of the neutral diatomic molecules now known has absorption lines starting from the lowest rotational level which agree with them. However, a molecular origin is certain and it seems that the study of ionized diatomic molecules such as CH^+, NH^+, NO^+, CN^+, C_2^+ would be particularly interesting. The polyatomic molecules also supply a wide field of nearly unexplored possibilities. In any case, we can try to find whether any clue as to the identification of the lines of Table 3 can be derived from the lines themselves. If, as Adams has suggested, the first three sharp lines of Table 3 are connected and if we classify them as the first lines of a progression in v′, we easily derive the values of the parameters in the expression of the vibrational energy referred to the ground state as zero

$$E_{v'} = av' - bv'^2$$

Then, from dEv'/dv', we get some idea of the limiting v′ and finally of the heat of dissociation D′ of the molecule in its upper electronic state ($D' \sim 1$ volt). Consequently we can be certain that the potential energy curve of the upper state is shallow.

The broad lines could be considered as having a molecular origin if the molecules have very shallow potential curves, or if they were released by dissociation of more complicated molecules or solid particles, the products of this dissociation keeping some rotational energy and the transitions toward lower levels being strongly forbidden. One could also consider the case where the transitions between two rotational levels are so weak that the processes of populating of the upper level exceed the processes of emission. There is also the possibility of attributing them to solid particles. In this respect, the strong correlation existing between the intensities of these broad lines and the color excess, generally connected with the existence of small solid particles, is a favorable argument. Only molecular crystals or amorphous metals could exhibit such narrow bands since in ionic or metallic crystals the strong interactions between the neighboring particles will, even at the very low temperatures of interstellar space, give rise to much broader features. We could expect interstellar crystals of light elements, such as solid oxygen, ice, CO_2, etc., and one may notice that solid oxygen has an absorption band at λ 5795.7 (V. Henri) and that one of the broad features of Merrill is at λ 5796.9. But, unfortunately, the knowledge of the optical properties of these states of matter is very limited and until considerable progress in this field has been made, no conclusion can be reached.

Now we can review very rapidly the difficulties and questions which

arise from the existence of interstellar diatomic molecules. First of all, the two components of the expected molecule must approach each other to a distance of the order of say 10^{-8} cm. For C and H, if we take a kinetic temperature of the order of 10,000 degrees, there will be such a collision, per cm^3, every 10^5 years. But in order that a molecule be effectively formed, the excess kinetic energy of the colliding particles must be removed from them during the small time τ of their collision. Generally, this is realized by means of a third particle. But it is easy to see that because of the very low density of interstellar matter such three-body encounters will be extremly rare. For CH, supposing that the third particle is an H atom, one finds that in a cubic centimeter such an encounter will take place every 10^{24} years, which is incompatible with the cosmic time scale.

The excess kinetic energy could be carried away by an electron, the molecule being formed in an ionized state, but, the difference between the potential of ionization and the heat of dissociation being generally large, this means that only those collisions where the particles have large kinetic energies could be useful. Furthermore, even when the energy requirements are fulfilled the probability of this process is still small and probably we can also disregard it. Finally, the excess energy can be emitted in the form of radiation. If the two atoms approach each other their energy varying along the potential curve of an excited state of the molecule, in general, one at least of the atoms is in an excited state and since we have seen that the excitation is extremely low in interstellar space we can be sure that this case will not be very frequent. In general, if the two atoms are in their ground states their energy during the collision will follow the potential curve of the ground state of the molecule. The excess energy can be emitted in the form of a vibrational quantum. Although the probability of pure vibrational transition is small, this last process will probably be in general the most efficient. However, for certain molecules like CH, which possess an excited state dissociating in normal atoms, the probability of an electronic transition being larger than the probability of a pure vibrational transition, the case where the energy of the two approaching atoms follows the potential curve of this excited state, will be more effective. According to the first process, homonuclear molecules will be practically nonexisting (only quadrupolar transitions) and this has perhaps a physical meaning since we have never been able to find C_2 in interstellar space. Once the process of dissociation and formation are known one can obtain the dissociation formula by equating the total number of molecules formed per second and cubic centimeter to the total number dissociated. Unfortunately, there is no good quantum mechanical computation of the coefficient of continuous absorption from the ground state and from the whole set of possible excited states for molecules (this would enable us to apply the Bates-Massey correction) so that an exact derivation of this formula is not now possible.

If one uses the ordinary dissociation formula relative to thermodynamical equilibrium multiplied by the factor of dilution δ and $\sqrt{T/T^o}$ (Swings-Rosenfeld) one finds, for instance for *CH*, using the abundances of *C* and *H* given by Struve,

$$N_{CH} \sim 10^{-10}/cm^3$$

while Dunham has derived from his observations

$$N_{CH} \sim 2.1 \cdot 10^{-6}/cm^3.$$

For *CN* (N_{CN} observed $\sim 10^{-6}/cm^3$) the discrepancy is still more marked. Of course, the observed values of *CH* and *CN* depend upon the adopted values of the oscillator strengths for these molecules. Dunham derived them from laboratory experiments and the values found: $f_{CH} = 0.060$, $f_{CN} = 0.075$, depend very much upon the heat of dissociation adopted for *CH* and *CN* ($D_{CH} = 3.47$ volts, $D_{CN} = 7.1$ volts) and upon the difficult evaluation of the carbon pressure in the graphite tube used. Thus, the observed abundance of *CH* and *CN* cannot be considered as definitive. However, there is no doubt that agreement between computed and observed values of *CH* and *CN* cannot be reached by modifications of the observed values only and it would be very interesting to have a good derivation of the exact theoretical formula under interstellar conditions which certainly differ very much from those of thermodynamical equilibrium. Finally, we must consider the consequences of Strömgren's theory. Since in general the heats of dissociation are small compared to the ionization potential of *H*, the division of interstellar space in regions of *H* and regions of H^+ will not affect the dissociation equilibrium of the molecules. But it can affect their ionization. This last problem of the repartition of the ionized molecules in interstellar space is complicated by the fact that we must consider also the direct formation of ionized molecules from one neutral and one ionized atom.

III. In the following discussion, Dr. Herzberg drew attention to the fact that the value of D_{CN} equal to 7.1 volts adopted by Dunham is probably too large and that he would rather suggest a D_{CN} of the order of 5.9 volts. This will increase f_{CN} and consequently decrease the observed abundance of *CN*. The opinion of Dr. Teller was that in this way, one could at best reduce the abundance of *CN* to something like $\frac{1}{5}$ of the abundance of *CH* and that more probably for some reason (perhaps predissociation) *CH* is very easily dissociated; this could explain why it is not much more abundant than *CN*. Dr. Teller also made some remarks on the populations of the rotational levels. One always supposes—and the identifications support it—that the rotation is very little excited in interstellar space. But for *CH* the population (or the mean life-time which, in first approximation, can be considered proportional to ν^{-3}, ν being the frequency of the emission line originating from the level considered) on a rotational level must be 10^9 times greater than on an electronic level ($\nu_{el}/\nu_{rot} \sim 1000$). For N_2, for instance, it would

be still greater—of the order of 10^{12} times—and furthermore N_2 being a homonuclear molecule we should still have to multiply this number by the ratio of the probability of the emission of dipolar radiation to that of the emission of quadrupolar radiation, which will bring the life-time on a rotational level of N_2 to a value equal to 10^{26} times the life-time on one of its electronic levels. If we adopt for the latter, 10^{-8} sec., this would give a life-time on a rotational level of the order of 10^{10} or 10^{11} years. This is of the same order as the cosmic time scale and consequently for homonuclear molecules other rotational levels than the lowest could be represented in interstellar space and such molecules could perhaps give rise to the broad lines observed.

Dr. Beutler thought also that this possibility should be studied carefully and the more so since one of the other possibilities advocated (amorphous metals) does not seem to him well founded and that, in any case, the laboratory work in this field is very far from being satisfactory. Dr. Teller and Dr. Beutler then discussed the possibility indicated by Dr. Swings that the molecules are formed in interstellar space on the ground level of the molecules with emission of the excess kinetic energy in the form of a quantum. If one considers for instance CH, one can take for the cross-section of C, $\sigma = 10^{-15}$ cm^2 and, since the duration of the collision is of the order of 10^{-13} seconds and since, in the mean, a time of the order of 10^{-7} second elapses before a quantum of vibration can be emitted, the probability of this process taking place during the collision is of the order of 10^{-6}. Consequently, the effective cross-section of C for the capture of an atom of H can be taken equal to $\sigma^* = 10^{-21}$ cm^2. If the kinetic temperature is taken to be equal to 10,000°, the mean velocity of an atom of C will be of the order of 5×10^5 cm/sec., and consequently, using the value of σ^* derived above, such an atom will undergo a successful collision with an H atom every 2×10^7 years. This time is still a small fraction of the cosmic time scale and this process can be efficient in interstellar space.

Dr. R. S. Mulliken then read a communication on polyatomic molecules. Following Adams the lines λλ 3745.33, 3957.72, 4232.58 seem to be related to each other, λ 4232 being the strongest. Their attribution to CH_2 is not excluded if one identifies λ 4232 as being due to the transition (without vibration) $^1A_1 - {}^1B_1$ predicted for this molecule. In that case λ 3958 and λ 3745 would correspond to transitions toward states with one quantum of vibration ν_2 and ν_1, respectively, the frequencies of these modes being 1640.3 and 3072.8 cm^{-1}. The latter is close to that for symmetrical CH_2 vibration in compound molecules (*e.g.* C_2H_4) and although the relative values of these frequencies look a little strange (usually ν_2/ν_1 is somewhat below rather than above ½) they are not impossible. For CH_2 one and only one transition is predicted in the visible and ultraviolet as is easily verified from the electronic configurations of the normal and the two lowest singlet and triplet excited states

$$N: 1s^2\ (a_1)^2\ (b_2)^2\ (a_1)^2,\ ^1A_1$$
$$A: 1s^2\ (a_1)^2\ (b_2)^2\ (a_1)\ (b_1),\ ^3B_1,\ ^1B_1$$
$$B: 1s^2\ (a_1)^2\ (b_2)\ (a_1)^2\ (b_1),\ ^3A_2,\ ^1A_2$$

From the forms of the orbitals (wave-functions) called b_1 and (the second) a_1, it is expected that the transition to the $^1B_1$ should have a fairly large f value. Transitions to the other states should be weaker by large factors (transition to the $^1A_2$ is forbidden by the electronic selection rules, but in polyatomic molecules weak transitions are still possible in such cases). From valence theory, it is certain that the molecule CH_2 should be triangular with apex-angle in the range 100° — 120°. It is then certain that the (second) orbital a_1 should be the most easily excited and an excitation energy from a_1 to b_1 of 3 volts (agreeting with λ 4232) is entirely reasonable. On the other hand, the changes in electronic structure by the electronic transition from $^1A_1$ to $^1B_1$ may be expected to produce a moderate weakening of the bond strengths and lengthening of the bonds, and more or less change in the angular equilibrium. This is in harmony with the observation of the strong λ 4232 and the weaker λλ 3745 and 3958. Additional weaker lines at shorter wave-lengths are also possible.

The observation of a single absorption line for each vibrational transition is exactly what is required for such a molecule as CH_2 in its lowest rotational state and the lowest excited rotational level should be about one third as high as in the case of CH and so should hardly give appreciable absorption in interstellar space.

The allowed electronic transition from

$$(s)^2\ (\pi)^4\ [\sigma],\ ^2A_1 \text{ to } (s)^2\ (\pi)^3\ [\sigma]^2\ ^2E$$

in CH_2, which probably has a moderate f value, should give a line in the visible or near ultraviolet. But actually the excited state ^2E must split into two non-degenerate states of a less symmetrical molecule (C_s symmetry) and this would give in cold absorption two lines of nearly equal intensity some distance apart (the additional doubling due to the spin will be negligibly small). One or more additional pairs due to excitation of vibration may also be found.

Finally, some other molecules which could have lines in the observable spectral region are

$$NH_2, OH_2^+, NH_2^+, NH_3^+, NH^+, CH^+, CN^+, C_2^+, OH^+, \text{etc.}$$

(NO^+ would absorb only in the vacuum ultraviolet.) Of all these, only an OH^+ spectrum has as yet been observed. For all the orders, predictions (similar to the above) can be made. Of course, if polyatomic molecules are definitely ruled out by the dissociation formula in interstellar space, then most of these molecules lose their interest and especially CH_2 and the considerations of it developed above.

After Dr. Mulliken's communication, Dr. Herzberg, Dr. Beutler, and Dr. Swings once more discussed the possibility of attributing the three lines of Adams to a diatomic molecule which, as Dr. Swings

pointed out, must then have an excited state with a very shallow potential curve. As a result of their discussion, considerable interest attaches to CH^+ which on account of its electronic similarity with BH, should satisfy this condition.

Dr. C. A. Rieke then presented an account of the theoretical computations of the oscillator strengths which she has obtained for the transitions

$$^2\Delta \leftarrow {}^2\Pi \text{ of } CH$$
$$^3\Pi \leftarrow {}^3\Sigma \text{ of } NH$$
$$\text{and } ^2\Sigma \leftarrow {}^2\Pi \text{ of } OH$$

She has obtained $f_{CH} = 0.010$ and $f_{OH} = 0.0004$. As the experimental value of f_{OH} is of the order of 0.0008, it is possible that the corresponding correction for the computed f_{CH} would bring its value more closely to the value $f_{CH} = 0.06$ adopted by Dunham. For NH, the f value turns out to be intermediate between f_{CH} and f_{OH}.

Addendum

The hopes aroused during the meeting in regard to CH^+ have been completely confirmed since then by an investigation of the spectrum of a discharge through helium to which a trace of C_6H_6 had been added, carried out by Dr. Herzberg and Dr. A. E. Douglas in their laboratory. They found bands with heads at λλ 4225.3, 3954.0, and 3743.4 A consisting of three singlet branches—P, Q, R—of a $^1\Pi - {}^1\Sigma$ transition. The R (0) lines of these transitions are at λλ 4232.57, 3957.71, and 3745.30, and agree perfectly with the three interstellar lines of Adams. On the other hand, the rotational constant B''_0 of the molecule is equal to 14.0 cm^{-1} which is very nearly that of CH (14.189), and indicates that, in any case, the emitter is a hydride molecule belonging to the second period of the periodic system. But among the possible hydrides, CH^+ alone can possess a system $^1\Pi - {}^1\Sigma$ (analogous with the isoelectronic molecule BH). Thus, we can be certain that the interstellar lines at λλ 4232.58, 3957.72, and 3745.33 are due to CH^+.

This is very important from an astrophysical point of view since we now know relatively strong interstellar lines due to the same molecule in its neutral and ionized states. We have already seen that this was badly needed since in the other case (Ca and Ca^+) the line of Ca was very weak and difficult to measure. If we had good values of the oscillator strength for these molecular lines and of the ionization potential of CH, we could derive a new and reliable value of N_e; a comparison between the distributions of CH and CH^+ molecules in space should also be considered.

Yerkes Observatory.

Time and Timekeeping*

By R. NEWTON MAYALL

At the Harvard College Observatory in Cambridge, Massachusetts, there is a collection of portable sundials, gathered from all parts of the world by the late Dr. Harold Ernst of Boston. Thousands of visitors view these small instruments each year. Great interest is expressed in them because they represent the device our forefathers used to tell time. The mechanical watch is little more than four hundred years old, and as late as the early 1800's the making of pocket sundials was a big business in many countries. Some French watch makers put sundials in the back covers of their cases. It is true that many of these watches could not be relied upon, so the small sundial was there ready to serve.

I mention the Ernst collection because it shows the development of timekeeping and timekeepers from the earliest times right down to the present; and a sundial is a good instrument to use when explaining time. Furthermore, this collection has served to make many people take a greater interest in time measurement.

We are so dependent on time, it is taken as a matter of course, and it is the one thing, perhaps above all others, we know the least about. Our watch is a convenient machine that makes it possible for us to regulate our lives comfortably—it tells us when to go to work, how fast a horse runs, how long it takes for the train to go from New York to Chicago, and how much faster we can travel between those two cities by airplane than by train.

Our lives are practically governed by a thing called time; yet how many of you know why that watch on your wrist or in your pocket tells time? What is the principle back of that machine with all it gears? Why it is possible to use such a mechanism? Few people know the answers to these questions and many other simple questions that refer to time measurement. This is evident from the number of questions I receive either directly or through the mail, that require an explanation of time in order to answer them. Because so many of these questions are of general interest and asked by men and women like you, and even by school children, I am using them as a basis for what I am going to say about time and timekeeping.

Time is man-made. Here in the United States a great many places have set their clocks and watches ahead one hour in order to allow the business man and many others to be outdoors in sunlight for a longer period of time than he would be under the accepted Standard Time

*Broadcast from station WRUL, in the series of Harvard Radio talks, on May 31, 1941. For other talks in this series, see POPULAR ASTRONOMY for April, 1941, p. 191; May, 1941, p. 236; June, 1941, p. 311; August, 1941, p. 365; and October, 1941, p. 428.

System. Of course, instead of setting the clock ahead we could get up one hour earlier and stop work an hour earlier, and get the same result. But somehow no one likes that idea. If you have been used to getting up in the morning at six o'clock, you would rather set the clock ahead and continue to get up at six o'clock than you would to get up at five.

Some people like this idea of setting the clock ahead, and others do not. Those who do not, usually set forth the argument against it, that "we should not change God's time." God's time is the natural division of light and dark which we are pleased to call night and day, notwithstanding the fact that for many centuries a day comprised the period from one sunrise to the next, or as some peoples defined it—from one sunset to the next sunset.

Thousands of years ago God's time was used, but as man developed in culture and knowledge, and expanded his activities, these two divisions did not suit his needs. It is only natural that primitive man should make use of the sun and what seemed to him the sun's regular motion. He found he could use it to divide the daylight into short periods—just how or into what number of parts, or how he recorded them we do not know, because the known history of timekeeping really begins about 1500 years before Christ, which, incidentally, is also the date of the earliest known sundial.

The marks on this early sundial show that the daylight period was divided into twelve equal parts throughout the year, thus giving what we call the natural or unequal hours. You can readily see that such a procedure would result in longer divisions in the summer than in the winter.

The natural hours were used for many centuries, and, strange as it may seem, such an ancient system is still used in some parts of the world today. But at the beginning of the Christian Era, a discovery was made that revolutionized timekeeping and paved the way to the method of timekeeping we use today. This was the discovery that if a rod was attached to a flat, level plate, in such a position that it pointed to the celestial pole, greater accuracy in timekeeping could be obtained.

The celestial pole is not marked by the North Star. It is that point in the sky through which the north-south axis of the earth would pass if the line of the earth's axis were extended far out into space. Therefore you can see that the sloping rod, or gnomon as it is called, would lie parallel to the earth's polar axis, and the sun would appear to move about the gnomon as an axis. At least that is the way the ancients thought of it, for in those days the earth was placed at the center of everything and the sun, moon, planets, and stars were supposed to move around a stationary earth.

This great discovery of the sloping gnomon simplified the making of solar timepieces, and it is only natural that the new theory would lead directly to the use of twenty-four equal parts for the day. Furthermore, the celestial equator is nothing more than the projection of the plane

of the earth's equator; similarly many other imaginary lines in the sky are the counterparts of terrestrial lines, even though they may be called by another name, when they are used in the sky.

Many centuries passed before mechanical devices were contrived to tell time, but their principle is the same as that upon which the sundial is constructed. This principle goes back as far as the beginning of the Christian Era. Therefore if we know the principle of the construction of a sundial we know the principle of modern timekeeping, which is, briefly, that we assume the sun to travel at a uniform rate along the celestial equator, and mark off equal intervals of time. That is why I wanted you to be sure to understand just what is meant by the celestial equator. I will repeat that principle in another way. The principle of timekeeping is based on the assumption that the sun travels at a uniform rate along the celestial equator, and, in doing so, it marks off equal intervals of time.

Although the old theory of the earth as the center with the sun moving around it has given way to the true modern concept of the sun as a center, with the earth and planets moving about it, the principle remains the same. Therefore, today timekeeping is based on the period in which the earth makes one complete revolution upon its axis. This period we call the day, and it is divided into twenty-four equal parts called hours, which in turn are divided into sixty minutes, and the minutes into sixty seconds. This period, called the day, may be measured by observing the apparent motion of the sun or the stars, and the period is determined when the object observed, having completed one apparent revolution, returns to the starting point. (I say apparent revolution, because we accept the idea that it is the earth turning rather than the stars moving; therefore any motion of the stars is apparent.) Thus a solar day would be the interval between two successive crossings of any particular true north-south line by the sun.

Because the sun is not fixed as the stars appear to be, but appears to move irregularly across the sky, completing a circuit in a year, it is only natural that the length of the solar day should vary. Obviously then, a clock which ticked off twenty-four hours in a solar day would be an irregular mechanism, hard to construct. And furthermore, it would not serve our purpose today.

We look upon a good clock as one that runs evenly day after day. For such a clock the days must be of equal length. If we average the values for the length of the solar days throughout the year, a mean (or average) solar day will be obtained. A clock adjusted to tick off twenty-four equal hours during this mean day will show what we call mean solar time. The irregular solar time is called apparent (or real) solar time.

Therefore if we have two clocks (one showing mean time and the other apparent time) reading zero hours, and if we start them off at exactly the same moment, it is evident that very soon, they will disagree.

The difference between their readings is called the equation of time. This difference between the two clocks can be computed and tabulated for each day in the year. With such a table it is possible to obtain the reading of one clock from the reading of the other. In a similar manner it is possible to obtain mean time from a sundial that shows apparent time.

The equation of time is not quite so unfamiliar as you may think when you hear me mention it. If you will look at any good globe, you will see a figure eight marked about in the middle of the Pacific Ocean. That figure eight is nothing more than a picture of the equation of time, and by it you can tell how many minutes the sun is ahead of or behind the watch, and also at what latitude you would have to be, on any particular day, to see the sun directly overhead at noon. When you see the words "sun slow" or "sun fast" in your favorite almanac, it is just another way of saying—"equation of time."

So much for the story behind the mechanism of the watch and clock. Before telling you how our clocks are regulated, I want to remind you that although the present generation was born in a so-called Standard Time Era, our fathers and grandfathers can well remember the days when each city had it own local mean time. The clocks in various cities disagreed by an amount equal to the difference in longitude between the cities. This difference amounted to four minutes of time for each degree of longitude. In time measure, fifteen degrees of longitude are equal to one hour; and 360 degrees (a complete circle) is equal to twenty-four hours, or one day. Therefore a clock in Boston, Massachusetts, would have been sixteen minutes ahead of one in New York City, because the difference in longitude between these two cities is four degrees (four times four minutes is sixteen minutes); and because Boston is east of New York the sun would arrive overhead in Boston sixteen minutes before it would be seen overhead in New York; which means, the Boston clock would be ahead of the New York clock.

As the railroads stretched their steel fingers farther and farther, and the automobile loomed upon the horizon, our way of life was speeded up. These machines made it possible for us to go from one place to another in much less time than was required with a horse and buggy; and this method of using a different time for each city became inefficient.

In 1883 our present Standard Time System was put into effect in the United States and in 1884 the major countries of the world accepted it. The following ten years found practically every country in the world using Standard Time.

There are a great many people who do not know what Standard Time really is. This is not so strange because Standard Time and mean time are frequently referred to as one and the same thing. In a way that is correct, but I like to think of them separately in this manner: Standard Time is mean time, but mean time is not necessarily Standard

Time. The reason for this somewhat paradoxical sounding statement is that Standard Time is just a convenient method of using mean time over large areas.

Standard Time is only a method of timekeeping devised for the purpose of enabling us to live more comfortably and without confusion—that is, to work and travel over large areas without having to constantly change our watches. In order to do this the earth was divided into twenty-four zones or areas corresponding to the number of hours in a day. Everybody's watch in each zone would show the same time, but in two adjacent zones the watches would differ by exactly one hour.

Beginning with the zero meridian of longitude, known as the Greenwich meridian, the meridians at intervals of 15 degrees—that is, the longitude 15°, 60°, 75°, and so on—were called Standard Time Meridians. The limits of a zone, within which all watches would agree, were determined by lines about seven and one-half degrees east and west of each Standard Time Meridian.

This did not make it necessary to change the construction of our watches in any way; nor did it change the use of mean time, because the time shown by the watches in any Standard Time Zone is really the local mean time of the Standard Time Meridian for that zone. Therefore, if you live on a Standard Time Meridian, such as the 75th, 90th, and so forth, your watch will show not only the Standard Time, but also local mean time. It is only on a Standard Time Meridian that mean time and Standard Time are one and the same thing. That is why I said,—Standard Time is mean time, but mean time is not necessarily Standard Time.

Whenever you go east or west of the Standard Time Meridian the local mean time differs from the Standard Time of the place by the difference in longitude, as expressed in time. So, you see, there is nothing very difficult about our method of keeping time. In the United States there are four Standard Time Zones. The Eastern Standard time zone refers its time to the 75th meridian, the Central zone to the 90th meridian, Mountain Time to the 105th, and Pacific Time to the 120th meridian. This enables us to travel many hundreds of miles east or west, always using the same time.

This system of timekeeping has brought comfort to countless millions without regard for race, creed, or color. Yet we very seldom hear anything about the man who was responsible for it all. The inventor of the Standard Time System, as we know it today, was Charles Ferdinand Dowd who was the principal of a girl's seminary in Saratoga Springs in New York State.

Dr. Dowd died in 1904. All that remains to signify his important contribution to the world is a small bronze tablet in the Presbyterian Church in Saratoga Springs—placed there by a few of his former students. I wish there were time to tell you more about Dr. Dowd, for his

life is an interesting story, but there is more to be said about timekeeping itself.

The public demands precise timekeeping. I don't know why, because today the man in the street can obtain time a million times as accurate as he has any possible use for. But science continues on its way. If more precise timekeeping can be brought about, we can trust the scientist to devise means of obtaining it and to provide it, whether you and I as citizens have any actual use for it or not, because the scientist and astronomers do have uses for such great accuracy.

How would you like to have a clock that tells time to one thousandth of a second? Such a clock has been devised and several of them are in use. I suppose you are wondering what anybody would do with such an instrument. The answer is not what you might guess, because, believe it or not, this precision clock is used by the ordinary business man and it is used in radio. It was devised to determine frequency in units of time; therefore this clock has become a standard which is used to set up other standards. For example: when you want to tune in a certain radio station, you turn the knob on your set until the indicator hand on the dial points to a number which represent the number of kilocycles upon which the station operates. If the station did not always send out its signals on the same frequency you wouldn't waste your time listening.

Accurate operation of all radio stations is dependent upon a standard, and this clock aids in the job of making a station stay on the frequency allotted to it.

The other day I visited the factory of the General Radio Company in Cambridge, Massachusetts, where the clock was developed, that I might see it in operation. As I stood in front of the dial with its swiftly moving hands, reading it to the nearest thousandth of a second with greater ease than to read the nearest second on my watch, it was hard to realize I was not in a time observatory or a watch factory, but in an ordinary business plant that actually makes use of a thousandth of a second so that your reception of radio will continue good.

Can you visualize what such accuracy in timekeeping means in terms of common every day things? A clock which gained or lost a thousandth of a second every day in one thousand days or two years and six months would be "out" only one second. If you had a weighing scale as accurate as this clock you could detect the difference in the weight of a thousand tons of coal if you should add four lumps of sugar to it.

Radio is not the only use for such a clock. It has been used for timing the flight of bullets, and in measuring the speed of light.

The astronomer is not the only one to be thanked for making such precise timekeeping possible—he must share the honors with the mathematician, the mechanic, and others. But certainly without the astronomer's knowledge of the movement of the stars and other heavenly

bodies, we might still be using water clocks, sinking bowls, time lamps, candles (marked off in sections), and sand glasses at night; and sundials that tell the unequal hours by day. Man has always had some means of telling time. Our present methods were not devised over night—they are the result of centuries of development, particularly in the sciences of astronomy and mechanics. The mechanic makes possible the delicate, precise mechanisms in use today.

Next time you hear anyone wanting to change God's time, don't forget, we cannot change what we do not use—Time is man made.

* * * * *

I must confess that time means a lot more to me than just a means of governing my actions. I like to play with it, in the same way you cut up a square and put the pieces together again in the form of a rectangle which seems too have less area than the original square. You are familiar with that trick, and similarly you can have a lot of fun with time. One way is to make sundials; but here is one stunt you can try on your friends. Along about June 21, someone will probably say to you "The longest day of the year will soon be here." Then you tell your friend he is wrong and see what happens. Mrs. Mayall is sitting across the table frome me. She is an astronomer on the staff of the Harvard Observatory. Let we ask her about it, then we'll find out who is right.

Mr.Mayall—Isn't June 21 the longest day of the year in the northern hemisphere?

Mrs. Mayall—No. It doesn't make any difference what hemisphere you are in, June 21 is not the longest day of the year.

Mr. Mayall—Well if it isn't, what day is the longest?

Mrs. Mayall—You have already explained what a day is, therefore my answer was based on your definition, and if your listeners try the simple experiment you outlined for measuring the length of the day, they will notice that the length of time from one noon to the next, increases and decreases throughout the year, and that on September 17, the day will be 47 seconds shorter than on January 1, and on December 23, the day will be 51 seconds longer than on September 17. Therefore, September 17 is the shortest day in the year, and December 23 is the longest day. But, of course, if you are talking about the length of daylight, then June 21 is the longest in the northern hemisphere and December 23 in the southern. So you see, any one living in the southern hemisphere, has an advantage over us up here in the north, because for him not only is the longest day on December 23, but also the longest period of daylight as well. Therefore, be careful how you bet and with whom you bet, on which is the longest day of the year.

Mr. Mayall—While you are in the mood of answering questions, will you tell our listeners a little more about that figure eight on the globe that I mentioned as representing the equation of time?

Mrs. Mayall—I think you said enough, but I would like to tell them what can be done with it.

Mr. Mayall—Go ahead. I'm sure they will find it interesting.

Mrs. Mayall—That figure eight is more commonly referred to as the analemma, and it has several practical applications. For example: a stationary analemma can be used to check your watch. If you know the height of an upright pole you can figure out how long the shadow will be at noon. By turning this problem around, if the length of the shadow is known, the height of the pole can be obtained, and if you know the length of the pole and its shadow, the latitude can be found.

Mr. Mayall—Yes, you can do a lot of things with time, and here is a real brain teaser I found in Mr. Ripley's book. "A day is forty-eight hours long, not twenty-four." Can you figure that one out?

Mr. Mayall—If you want to know the answer, write to me at the Harvard College Observatory, in Cambridge, Massachusetts. Now my *time* is up and I will say—good afternoon.

Report of the Conference of Teachers of Astronomy at Yerkes Observatory, September 7, 1941

By JOHN H. PITMAN

More than seventy teachers of collegiate astronomy attended a conference devoted to teaching problems at Yerkes Observatory on Sunday afternoon, September 7, 1941. Novel and ample quarters for this and the following sessions were provided on the ground floor beneath the great dome of the forty-inch refractor. Here in convenient proximity were registration desk, assembly room, and an extensive astronomical exhibit arranged by Dr. Jesse Greenstein of the Yerkes Observatory.

A dozen observatories contributed to the display. The walls were covered with photographs of observatories and equipment, photographs of the Milky Way, and greatly enlarged spectra. Cabinets of standard 3¼ x 4 lantern slides, and 2 x 2 Kodachrome slides of observatories with color enlargements thereof attracted much attention. Original negatives of Barnard's proper-motion star made with Yerkes 10-inch camera and small-scale spectra secured at the Leander McCormick Observatory were available for study. Fifteen publishing houses sent a wide variety of titles, from constellation study through textbooks to the latest monographs. The Milwaukee Astronomical Society had an exhibit on meteor observations which included observing sheets, mountings for small cameras for photographing meteor trails, and a simply constructed three dimensional model of a meteor trail. Two pieces of plywood each approximately eight inches square were nailed at right angles. On the horizontal piece was fastened a section of road map; on the vertical, a circumpolar chart. On the latter were drawn the apparent paths as seen from two observing stations. Wires connected the beginning and

terminal points of the two trails with the appropriate observing station. A paper meteor trail joined the intersections of the wires. This model is recommended for students who have difficulty in visualizing three dimensions.

The conference was a result of a previous meeting held in Philadelphia on January 1, 1941, and of suggestions received to the questionnaire distributed last spring. This report includes the results of the questionnaire, the papers presented at the meeting, and the action of the conference or committee elected by the conference, and is best presented by subject matter.

Pronunciation and Spelling. Eighty-nine percent of those replying thought a preferred list of spellings and pronunciations should be prepared and adopted. Dr. Samuel G. Barton of the University of Pennsylvania presented a paper pointing out some of the present difficulties. (Read by Miss Dorothy Davis of Princeton.) The conference desired that work on this problem should continue. A committee consisting of Dr. Barton, Rev. Daniel J. McHugh of DePaul University, Chicago, and George A. Davis, Esq., of the Buffalo Museum of Science was later appointed to prepare a preferred list of pronunciations and spellings and to report at the Christmas meeting. This committee has made considerable progress to date.

Astrology. Written comments received on the subject of astrology varied from "Fight the Racket," "Barnum was right" to numerous suggestions for increasing the publicity of the fallacies of astrology. Dr. Hynek of Ohio Wesleyan, from a study of the data listed in the American Men of Science, showed that one had a slightly better chance in predicting an individual's life by flipping a coin than by reading his horoscope. Dr. Bart Bok and Mrs. Margaret Mayall of Harvard College Observatory have published a paper on this subject in *Good Housekeeping*. Discussion at the conference was started by the reading of a paper by Mrs. Mayall. She is making a collection of advertisements of astrologers and invites contributions, sent with date and source of publication. Professor Earle G. Linsley of Chabot Observatory, Oakland, California, spoke briefly of the activities of astrologers on the west coast and of his own effort to induce school children in their thinking to place astrology on a par with myths, legends, and superstitions.

Motion Pictures. The McMath-Hulburt Observatory has been engaged in making a series of films for educational purposes. Dr. McMath writes, "We think we have solar prominences, spectroheliograms of the solar surface, and sunrise and sunset on the moon sufficiently well covered for educational films. We are planning more work on white-light pictures of the sun to show solar rotation and granulation, on Jupiter's rotation and satellite phenomena, including shadow transits and eclipses, on occultations, and on asteroid motions. A tentative program with a wide-field, small-scale camera to show motions of the moon through the

sky with reference to stars and planets is also under development." Dr. Orren Mohler stated that the program was proceeding according to plan. Some teachers prefer to own the films but many are interested in a central agency from which the films could be rented. There are institutions in the east, central west, and far west which maintain libraries of films for rental. It will probably be necessary for one or more central agencies to purchase the positives and lease them at a price which will cover the depreciation or underwrite the loss. The writer invites suggestions for financing this project.

Publications. Two papers concerning publications were presented. The one on POPULAR ASTRONOMY was prepared by the editor, Professor Curvin H. Gingrich, and read by Dr. N. Wyman Storer of the University of Kansas. The various departments of POPULAR ASTRONOMY were described, and their value as teaching aids pointed out. Suggestions were made for increasing the usefulness of the magazine. Dr. Gingrich made the statement, "Just as each of the departments now being maintained is the result of voluntary, capable, and greatly appreciated services, rendered by an individual, so it might be that some teacher would be interested in promoting a department for the teaching of astronomy. Indeed, this meeting might wish to designate one of its members to do this. POPULAR ASTRONOMY would welcome such an appointment." The meeting did not feel prepared to do this at the time and deferred action. Charles A. Federer, Jr., Editor of *The Sky,* spoke on that publication and the courses of instruction at the Hayden Planetarium. He also expressed the desire to publish articles of particular value to teachers. Attention was called to the series of sketches of prominent astronomers in the issues for the current year. This series should be of value to teachers of Descriptive Astronomy.

Lantern Slides. To those who have large libraries of standard size, 3¼ x 4 lantern slides, the question of adopting the smaller 2 x 2 slide is not important. To those who have a restricted budget or who wish to supplement their collection with Kodachrome photographs the smaller slide offers great advantages in original cost, storage space, and ease of handling. A science which relies so largely on the photographic process as does astronomy should not hesitate to present the subject matter in the most attractive photographic form.

Dr. Charles H. Smiley of Brown University showed a selected list of these smaller slides. Those interested are invited to write him, sending a list (in order of preference) of the fifty or more slides which should be made first. A standard list of fifty will be made upon the basis of these suggestions: those interested will be notified and sets will be made as ordered. Slides may be made of diagrams and drawings as well as of direct photographs of celestial objects. All teachers can aid in this project now if they will inform Dr. Smiley what they would like and what they can offer in the way of material. Dr. C. C. Wylie of the

University of Iowa showed a series of standard size slides mostly on meteors and meteorites. Those interested in such slides should communicate with him.

Graph Sheets. Professor J. W. Campbell of the University of Alberta described an astronomical graph sheet from which one could read positions in the horizon and equator system of co-ordinates, with an accuracy of one or two degrees. These are very useful in class work. A full description will appear in the *Journal of the R.A.S. of Canada.*

Advanced Courses in Astronomy. Professor Marjorie Williams of Smith College opened the discussion on "Background for Graduate Work," and brought up the following questions: Would graduate work be more successful for both students and teachers if all colleges had approximately the same requirements for the undergraduate major? Should there be some uniformity in the content of advanced courses, such as Practical Astronomy, Astrophysics, etc.? Do teachers feel that it is necessary to make an effort to popularize the elementary course in order to secure students? What should the teaching observatory do for the public and for the students not in astronomy classes. Miss Williams would like to receive comments on these or related questions.

Books. Many interesting points were raised in replies to the questionnaire. "I would like a good bibliography for Descriptive Astronomy with a view to purchasing books, not texts." Some said book reviews are not critical enough. "I would welcome an agency to which I could write for information concerning an adequate library for introductory courses, minimum equipment necessary, information, books, and other sources available concerning the construction of telescopes and other equipment for the amateur. Even a small fee for such a service would be well worth it." Professor C. C. Wylie stated that he had been asked to prepare a book for Teachers' Colleges and Junior Colleges. It has been suggested that since most students in such schools are not science majors, considerable attention be given to the contacts of astronomy with every day life, and to the distinction between the facts of science, strictly speaking, and theories which are little more than hopeful speculation. Comments and additional suggestions are invited.

Laboratory Material. Professor Philip C. Keenan, of the University of Chicago, writes "The teaching of astrophysics offers especial difficulty because the source material is widely scattered in observatory publications and the subject is developing rapidly. I think the study of spectroscopic problems would be greatly helped if a large selection of prints of stellar spectra of various dispersions were available for practical work in classification and intensity estimates. It would be fine if such prints were obtainable at low cost, or perhaps a permanent organization could be established to handle prints, slides, and other laboratory material." Many teachers who regard laboratory work as a neces-

sary part of the introductory course in astronomy find that telescopes, microscopes, and other physical equipment maintain interest more successfully than spheres and graph paper. A wide variety of exercises seems desirable, including many designed for clear nights with instruments. Because of the variation in types of equipment available, what is practical for some colleges will be impractical for others. In any case the work should compare favorably with that given in the beginning laboratory courses in other science departments. With a view to assembling such material, Professor Alice H. Farnsworth of Mt. Holyoke College would be pleased to receive copies of laboratory exercises, especially those which have been found particularly effective.

The conference selected a committee consisting of John H. Pitman, C. C. Wylie, J. J. Nassau, Charles H. Smiley, Miss Marjorie Williams, and Miss Alice Farnsworth to continue the work and arrange for future meetings. Professor Nassau is planning a session for the teachers at the Christmas meeting of the A.A.S. at Cleveland and Professor Wylie, secretary of Section D of the A.A.A.S. is planning a session for the Dallas meeting. The organization of the teachers is still in the formulative state and the committee would welcome suggestions.

Denver's New Sundial

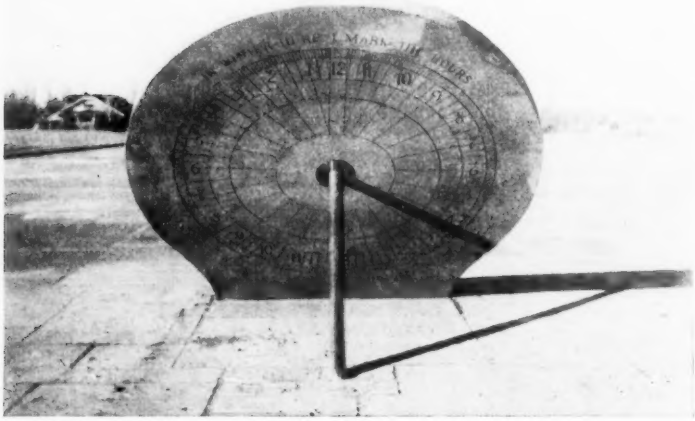
By S. A. IONIDES

"A paradox, a paradox, a most ingenious paradox!" These words were originally applied by W. S. Gilbert in "The Pirates of Penzance" to another astronomical anomaly. The problem there was whether a boy born on leap year day, February 29, in, say, A.D. 1900, would reach his twenty-first birthday in 1921 or 1984. The paradox in Denver's new sundial is how the shadow manages to point uphill. The illustration of the north side of this dial was taken just before sunset in the middle of June. The dog-bearer in the picture is my daughter, my co-author of "Stars and Men," also of "The Zodiac" in the March number of POPULAR ASTRONOMY.

A modern sundial, when properly made and installed is a miniature model of our Earth set parallel to its axis and rotating with it, as our Earth rotates on its axis. Our sundials, being on the surface of the Earth are somewhat eccentric to the Earth's axis, about which they rotate, but this eccentricity of a few thousand miles is so small, compared to the 93,000,000 miles between the Earth and the Sun, that it may be ignored.

The gnomon of a sundial must always be parallel to the polar axis of the Earth and usually the sphere is cut to leave a plane and the type of sundial is named by the direction of the cut. The more common types are the horizontal, the vertical and parallel to a cardinal point of the compass, the polar, and the equatorial.

Denver's new sundial is equatorial. This type with the plane parallel to the equator is of ancient origin, but is rarely used today. R. Newton and Margaret L. Mayall in their book "Sundials" do not give any photograph of one, though they write freely of them. Armillary sundials, which are hollow spheres cut away, are along the same line and have their hours shown around the inside of the equator and are much more common.



DENVER'S EQUATORIAL SUNDIAL
(Photograph taken on February 26, 1941.)

When Mr. George E. Cranmer, Manager of Improvements and Parks in Denver, decided on a sundial for the centerpiece of the large sandstone platform in Denver's new Mountain View Park, he drew his inspiration from an ancient small Chinese sundial, which he had seen in San Francisco, and called on me to design one of that type.

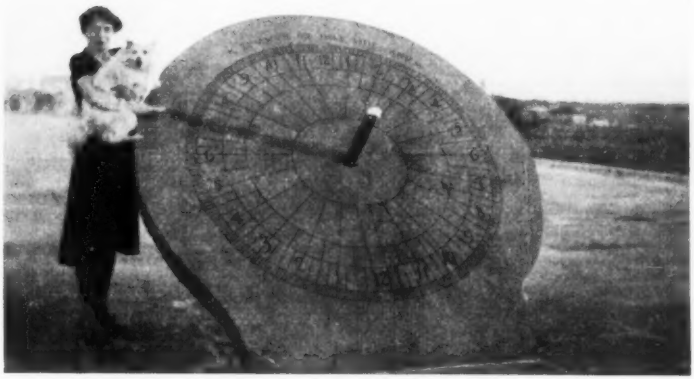
The dial had to be large to be of value to its location. The slab from which it was made measures six inches in thickness and seven feet in diameter. The outer circle of the dial is five feet, eight inches in diameter. The gnomon, which also serves as a support, is a three-inch stainless steel shaft.

The slab is of sandstone from the same quarry near Lyons, Colorado, as that from which the sandstone for the platform had been quarried. The markings were transferred from the drawing to a composition rubber covering, through which the lines were cut and sandblasted in the shops of the Erickson Memorial Company of Denver.

The arrangement follows the Chinese pattern and like it has the hours

shown all the way around the clock, even though at the latitude of Denver the limits for the sun's shadow are 4:00 A.M. and 8:00 P.M.

The meridian for Mountain Standard Time (7 hours west of Greenwich) lies along Navajo Street in the City of Denver and the sundial is only 17 seconds east of this meridian, so no correction for longitude was made and the reading of the upper edge of the shadow gives local apparent time. An analemma to give the correction for equation of time



DENVER'S EQUATORIAL SUNDIAL
(Photograph taken at 7:15 P.M. on June 17, 1941.)

has been designed but not yet built. This will carry the combined corrections for equation of time and longitude and will enable anyone, without even the slightest knowledge of astronomy, to set his watch to Mountain Standard Time with substantial accuracy from the reading of the shadow and the correction shown by the curve of the analemma.

The equatorial dial *may* have been created by the Chinese, as to them is given the credit of setting a large ring in the ground parallel to the equator to show the changes of the seasons. With this arrangement the sun shines on the southern side from the beginning of the year up to March 21, then on the northern side till September 23, and then back to the southern for the balance of the year. When the Romans saw these rings, they considered them too large to be used on fingers, so they named them bracelets, or *armillae,* and that name has persisted with armillary sundials and spheres.

The same program is followed naturally with equatorial sundials and they must be graduated on both faces to be of service throughout the year. Equatorial sundials have the marked advantage of having all the

hour angles of equal size and so the same dial can be used irrespective of latitude and merely requires setting at the proper inclination and direction to give correct readings. Most other types give reasonably correct readings only within a small range of latitude.

In conformity with tradition and to convey the seasonal features to visitors, this sundial has a motto inscription, which tells of the shift from side to side. On the north side it reads:

In summer on this side, and—

and on the south:

In winter here I mark the hours.

To return to the "most ingenious paradox," the explanation is simple. The shadow does point uphill, but only because the gnomon also points uphill and at a steeper angle, its inclination to the horizonal being equal to the latitude of its location, 39° 43′, while the rise of the shadow is but 20° as measured by the hour angle.

Every reader will, of course, have spotted the fallacy in the paradox mentioned at the beginning. The example given was purely fictional. It could not have occurred. The year 1900 A.D., though divisible by four, was not a leap year, as the Gregorian Calendar rule calls for the omission of the century years, except when the number of centuries is divisible by four, and nineteen is not so divisible. In 1900 A.D., there was no February 29!

DENVER, COLORADO, JULY 24, 1941.

A Planetary Cluster in 1 A.D.

By R. B. WEITZEL

Four planets—Mars, Venus, Mercury, and Jupiter—were visible in the eastern sky for twenty one mornings, from the heliacal rising of Jupiter on October 28 to the heliacal setting of Mercury on November 17, in the year 1 A.D. The following are the positions of the planets and sun, with Mercury and Jupiter in approximate conjunction, on November 5, 6:00 A.M., twenty-two minutes before sunrise at geographical longitude 35° east, latitude 32° north.

	L	b	λ	β	α	δ
Mars	191°.32	+0°.72	202°.84	+0°.46	201°.26	−8°.55
Venus	179.14	+2.90	203.58	+1.31	202.29	−8.04
Mercury	164.11	+4.54	205.35	+1.48	204.00	−8.53
Jupiter	202.42	+1.21	205.30	+1.03	203.79	−8.93
			M.L.	Eq.T.		
Sun	221°.22		222°.14	−3°.40	218°.74	−15°.35

The rising of the planets, neglecting refraction, their hour angles, azimuths from the north, and stellar magnitudes, are tabulated.

	Rising	H.A.	Az.	Mag.
Mars	4:58 A.M.	84°.61	100°.10	+1.7
Venus	5:01 A.M.	84.94	99.49	—3.4
Mercury	5:09 A.M.	84.62	100.07	—0.7
Jupiter	5:09 A.M.	84.36	100.55	—1.3

Mars, Venus, Mercury, and Jupiter rose in that order at almost the same place on the horizon with an azimuth difference of a degree. The altitudes of the planets are computed at intervals to 6:00 A.M., with azimuths for 5:40 A.M. in parentheses.

	5:10	5:20	5:40 A.M.	6:00
Mars	2°.49	4°.56	8°.67 (105°.82)	12°.71
Venus	1.91	3.99	8.11 (104.81)	12.18
Mercury	0.21	2.30	6.43 (104.27)	10.51
Jupiter	0.17	2.25	6.38 (104.72)	10.45

Mercury and Jupiter, half a degree apart, had the appearance of a double star; Venus shone brilliantly a degree and three-quarters above Jupiter; and Mars, somewhat higher, was a degree to the right of Venus. The four planets were clustered in a small field of two and eight-tenths degrees.

The remarkable configuration of Mars, Venus, Mercury, and Jupiter, on the morning of November 5, year 1 A.D., may have had some connection with the biblical story of the star of Bethlehem.

WASHINGTON, D. C.

Planet Notes for January, 1942

By R. S. ZUG

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. Apparent positions of the sun for January 1, and January 31, respectively, are: $\alpha = 18^h\,43^m.3$, $\delta = -23°\,4'.3$; $\alpha = 20^h\,51^m.7$, $\delta = -17°\,36'.8$. The sun will will be moving through the constellation Sagittarius until shortly after the middle of the month when it enters the constellation Capricornus. The earth will reach its position nearest to the sun for the year, that is, will be at the perihelion point of its orbit, January 2, 19^h.

Moon. Phenomena of the moon will occur as follows:

		h	m
Full Moon	Jan. 2	15	42
Last Quarter	10	6	5
New Moon	16	21	32
First Quarter	24	6	35
Perigee	Jan. 14	22	
Apogee	26	17	

Mercury. Mercury will reach greatest eastern elongation from the sun January 25, 12^h, and will be situated in the evening sky. On January 21, 1^h (January 20,

7 P.M. C.S.T.), the planet will be in conjunction with, and 6° to the south of, the planet Venus.

Venus. Venus remains an evening star during January but is rapidly approaching inferior conjunction (February 2). The planet will be stationary in right ascension on January 11.

Mars. Mars reaches eastern quadrature on January 29, and is well placed for telescopic observation. It passes from the constellation Pisces into Aries in the course of its rapid easterly motion during January.

Jupiter. Jupiter will be a conspicuous object in the night sky, located in the constellation Taurus. Opposition was passed on December 8.

Saturn. Saturn is nearing eastern quadrature and may be found in the constellation Taurus. The apparent motion of the planet is retrograde until January 24, when its motion becomes direct again.

Uranus. Uranus is moving in retrograde motion near the eastern boundary of the constellation Aries. Apparent position of the planet for January 1 and January 31, respectively, are: $\alpha = 3^h\,38^m.3$, $\delta = +19°\,15'.0$; $\alpha = 3^h\,36^m.4$, $\delta = +19°\,8'.9$.

Neptune. Neptune is located in the constellation Virgo, and after January 2 will be moving in retrograde motion.

Occultation Predictions

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b;* apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Date 1942	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30', LATITUDE +42° 30'			h m	m	m	°	h m	m	m	°
Jan. 1	130 Tau	5.5	10 6.9	+0.4	—2.2	132	10 50.8	+0.1	—0.4	235
8	89 Leo	5.8	3 25.2	—0.1	+0.9	104	4 25.5	—0.4	+0.6	292
26	γ Tau	3.9	20 18.6	—0.7	+1.6	86	21 28.4	—0.8	+2.0	240
27	70 Tau	6.4	0 15.7	—2.5	—0.8	111	1 32.6	—1.8	+2.0	223
27	75 Tau	5.3	2 33.4	—1.8	+1.4	45	3 41.1	—1.4	—2.8	299
27	θ^1 Tau	4.0	2 58.5	..	..	165	3 9.5	..	..	179
27	264 B.Tau	4.8	3 48.9	—1.3	—1.6	101	5 3.2	—1.0	—0.7	249
27	275 B.Tau	6.5	5 40.3	—0.6	—1.1	83	6 44.7	—0.1	—1.4	271
27	α Tau	1.1	7 2.6	—0.4	+0.3	39	7 41.2	+0.7	—2.7	316
28	111 Tau	5.1	6 26.8	0.0	—3.0	138	7 11.4	—0.7	+0.2	225
29	B.D.+18°1112	6.4	3 33.7	—2.0	—0.4	87	4 58.8	—1.5	—1.5	279
29	124 H' Ori	5.7	5 56.6	—0.7	—2.4	125	6 59.1	—0.9	—0.7	246
30	110 B.Gem	6.2	3 17.8	—2.1	—0.5	101	4 46.1	—1.9	—0.9	272
31	2 B.Cnc	6.2	6 3.9	—2.2	+0.5	60	6 59.1	—0.5	—3.4	330

Occultations Visible in Longitude +91° 0′, Latitude +40° 0′

Jan.	1	130 Tau	5.5	10	31.0	..	..	179	10	36.1	..	..	189
	7	56 Leo	6.0	11	6.9	..	..	32	11	16.6	..	..	20
	10	72 Vir	6.1	10	10.6	..	..	56	10	48.5	..	..	357
	26	70 Tau	6.4	23	34.5	−1.9	+0.8	98	0	53.8	−1.6	+2.3	229
	27	75 Tau	5.3	1	53.0	−1.9	+2.3	46	3	12.7	−2.4	−1.6	288
	27	264 B.Tau	4.8	3	19.8	−2.2	−1.7	111	4	38.1	−1.8	+0.8	232
	27	275 B.Tau	6.5	5	27.6	−1.1	−1.6	102	6	39.8	−0.9	−0.7	250
	27	α Tau	1.1	6	52.4	−0.7	−0.5	65	7	53.0	0.0	−1.9	290
	29	B.D.+18°1112	6.4	2	53.3	−2.3	+0.1	95	4	26.1	−2.2	0.0	262
	29	124 H³Ori	5.7	5	48.7	..	..	156	6	29.3	..	..	213
	29	292 B.Ori	6.5	9	38.6	+0.4	−2.5	140	10	20.6	−0.2	−0.2	233
	30	110 B.Gem	6.2	2	39.7	−2.0	0.0	109	4	6.3	−2.2	+0.9	256
	31	2 B.Cnc	6.2	5	21.3	−2.2	+0.1	87	6	45.6	−1.7	−1.9	300
	31	5 Cnc	5.9	7	33.4	−2.3	+0.8	56	8	23.7	−0.3	−3.8	336

Occultations Visible in Longitude +120° 0′, Latitude +36° 0′

Jan.	7	56 Leo	6.0	9	40.4	−1.9	+0.2	105	11	3.8	−1.8	−1.1	304
	8	β Vir	3.8	12	27.5	−3.3	+1.7	65	13	18.6	−0.5	−3.8	352
	10	72 Vir	6.1	9	27.1	−0.5	+0.6	106	10	30.9	−0.8	+0.1	300
	24	64 Cet	5.7	6	16.2	..	..	148	6	37.2	..	..	182
	24	ξ¹ Cet	4.5	6	58.2	−0.4	−1.3	93	7	59.0	−0.1	−0.2	239
	27	75 Tau	5.3	1	6.0	−0.3	+4.1	21	1	58.6	−2.7	−1.1	303
	27	θ¹ Tau	4.0	0	51.8	−2.3	−0.6	124	1	43.1	−0.5	+4.1	201
	27	264 B.Tau	4.8	2	8.4	−2.4	+0.4	100	3	31.9	−1.9	+2.3	227
	27	275 B.Tau	6.5	4	37.8	−2.7	−2.0	119	5	53.5	−2.2	+2.0	222
	27	α Tau	1.1	6	17.4	−1.8	−1.0	93	7	41.2	−1.4	−0.7	256
	28	115 Tau	5.3	7	19.9	−2.1	+1.4	46	8	18.7	−0.8	−3.5	315
	29	B.D.+18°1112	6.4	1	59.1	−1.2	+1.4	86	3	19.6	−1.6	+1.3	259
	30	110 B.Gem	6.2	1	56.1	−0.8	+0.9	100	3	7.8	−1.1	+1.6	254
	31	2 B.Cnc	6.2	4	21.2	−1.7	+0.6	102	5	46.1	−2.0	+0.6	270
	31	5 Cnc	5.9	6	22.6	−2.3	+0.1	97	7	54.5	−2.2	−1.1	287

Comet Notes

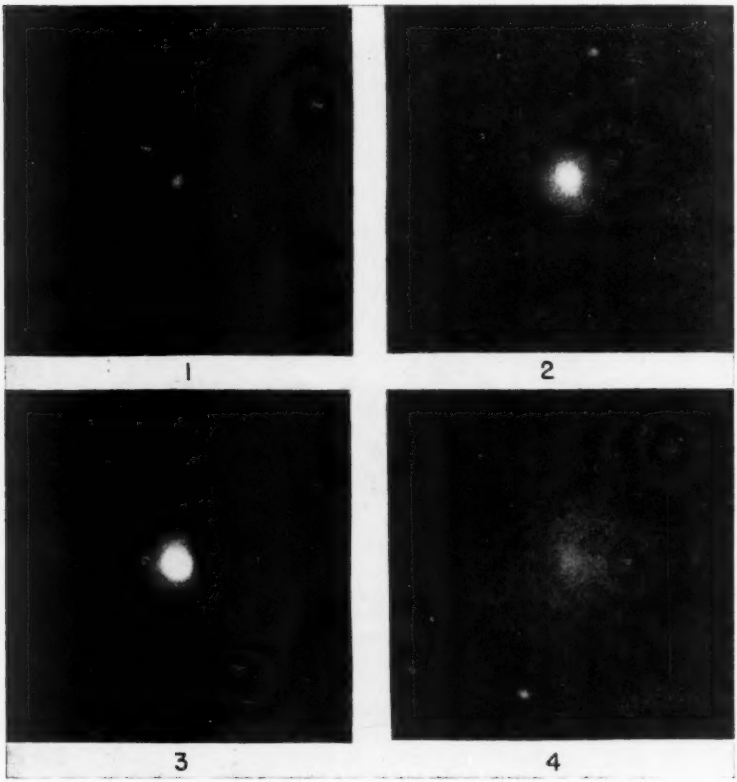
By G. VAN BIESBROECK

L. E. Cunningham has shown that the comet, supposed to be new, found by G. Neujmin on August 29, and provisionally designated as 1941 *f* (p. 449) was none other than Comet 1925 II (Schwassmann-Wachmann) which was already under observation for several months. Its ephemeris was given on p. 450. This has once more brought to the attention of the observers the large unexplained variations in brightness characterizing this object. It has a period of 16 years and moves in a not very eccentric orbit situated all the time between Jupiter and Saturn. Hence the distance is always large, 6 or 7 astronomical units, and it varies slowly. Of all comets this one is least expected to change in brightness. However, it has in the past shown very sudden and enormous changes. This fall again the fluctuations have been violent: a couple of days before Neujmin described the object as 13^M I had recorded it at Yerkes as 16^M or even fainter. In September again we find such estimations of magnitudes as: September 12 = 12^M; September 15 = 15^M; September 18 = 11^M.

Even more striking are the simultaneous modifications in the appearance. Figures 1-4 represent four short exposures obtained at the prime focus of the 82-inch reflector of the McDonald Observatory.

These rapid changes have not found any explanation so far. We can hardly expect to find in the comet itself the source of energy that caused these sudden outbursts. They seem more likely to be connected with some form of solar

activity. However, if that is so, it is hard to account for the fact that no other comet shows corresponding rapid modification. It is hoped that the mystery may soon be solved through spectroscopic analysis of the phenomenon. In the



RAPID CHANGES IN THE APPEARANCE OF COMET 1925 II (SCHWASSMANN-WACHMANN).

Fig. 1 Sept. 27 The comet appears like a star of magnitude 16 except that it is surrounded by a very faint circular nebulosity of 25″ diameter.

Fig. 2 Oct. 20 The very much enlarged nucleus is fuzzy and slightly eccentrically situated in a well-defined circular coma of 20″ diameter. Magnitude 11.

Fig. 3 Oct. 21 One day later the nucleus appears almost as a bright planetary disc 8″ in diameter. The coma has expanded to a diameter of 25″. Magnitude 10½.

Fig. 4 Oct. 27 The nucleus has faded back to 15M. The nearly circular coma has expanded to a diameter of 50″. The material of the nucleus seems to stream out in a broad fan opposite to the direction of the sun leaving the other half of the coma much fainter.

meantime it is highly desirable that a close record be kept of the changes in brightness.

COMET 1941 *f* (PERIODIC SCHWASSMANN-WACHMANN No. 2). The recovery of this expected comet is to be credited to H. M. Jeffers of the Lick Observatory. His first observation gives:

1941 Sept. 20.4898 $6^h\,34^m\,47^s.9$ $+20°\,13'\,43''$
Magnitude 17. Diffuse with central condensation.

This inconspicuous comet, first discovered at Bergedorf on January 17, 1929, proved to have a short-period orbit of 6.4 years. At its second return it was recovered by the writer on December 11, 1934, but it remained extremely faint. H. Q. Rasmusen of the Copenhagen Observatory deduced an accurate set of elements to represent both apparitions, and his prediction for the present return comes out remarkably close after an interval of seven years. The deviation from the observation was only three seconds of time in right ascension with a non-appreciable residual in declination. When last observed by the writer on October 26, the brightness corresponded to 15^M and there was a little tail, about 1′ in length, pointing away from the sun.

The comet will pass perihelion on February 13, 1942, and therefore will continue to brighten up. Rasmusen's ephemeris shows that the comet is favorably situated in the constellation of Gemini and that toward the end of the year it should become visible in small telescopes.

EPHEMERIS OF COMET 1941 *f*

1941	α h m	δ ° ′	Distance from Sun	Distance from Earth
Dec. 8	7 51.6	+18 13	2.20	1.36
12	51.4	18		
16	50.8	25	2.19	1.29
20	49.7	34		
24	48.1	45	2.18	1.24
28	46.1	18 58		
32	7 43.8	+19 12	2.17	1.20

Of the comets discovered earlier in the year only COMET 1941 *d* (VAN GENT) remains visible. It has been followed by many observers in its course through Ursa Major and is still accessible to small instruments. The ephemeris by Bobone is continued here:

1941	α h m	δ ° ′	Distance from Sun	Distance from Earth	Mag.
Dec. 4	5 31.8	+31 33	1.78	0.81	10.6
8	5 8.4	27 33	1.83	0.85	10.9
12	4 48.8	23 45	1.88	0.90	11.2
16	4 32.6	20 18	1.93	0.96	11.5
20	4 19.4	17 15	1.99	1.04	11.8
24	4 8.7	14 36	2.04	1.12	12.2
28	4 0.2	12 22	2.09	1.21	12.5
32	3 53.4	+10 28	2.14	1.31	12.8

It shows that while moving southwestward the comet loses in brightness more and more rapidly in December, but it seems certain that observations will be extended into 1942.

COMET 1941 *e* (DU TOIT-NEUJMIN) has faded away more rapidly than expected. Observations were no longer possible after the middle of October when the very diffuse comet was down to 16^M.

Williams Bay, Wisconsin, November 8, 1941.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

A. A.V.S.O. Variables in 1940-41: Mention was made in the "Notes" for November of the fact that over 37,000 observations of variable stars had been sent in to the A.A.V.S.O. headquarters by 123 observers during the year ending September 30, 1941. To be sure, more than three-fourths of the observations were made by about one third of the total number of observers; however, it must be kept in mind that the few observations made by the occasional observer have a definite value, especially when such observations are made after midnight, or when the stars are somewhat unfavorably placed for observation.

Many variables of regular and irregular type have been assiduously followed throughout the course of their light changes. The long-period variables follow, in most instances, the typical courses laid down by them over the years. Mention will be made here only of a few of the more interesting cases.

We present herewith observational facts concerning some of the spectacular variables, such as SS Cygni, R Coronae Borealis, R Scuti, the novae, etc.

Novae: RR Pictoris, 1925, continued to decrease very slowly, from magnitude 9.9 to 10.0, during the year. Nova Persei, 1901, has oscillated between magnitudes 12 and 13. DQ Herculis, 1934, has reached the eleventh magnitude on its decline to normal minimum light. The present rate of decrease is about $0^{M}.4$ per year. Nova Aquilae, 1918, fluctuated between magnitudes 10.8 and 11.8, with no evidence of periodic changes.

Nova Cygni, 1920, and Nova Lacertae, 1936, are both faint, the former below magnitude 14, and the latter at about that magnitude.

The so-called recurrent novae, T Pyxidis and RS Ophiuchi, were at minimum throughout the year, the former about magnitude 14, and the latter oscillating between magnitudes 11 and 12. T Pyxidis has been faint since 1920; if it does have another outburst soon, it should be closely watched, for it may pass through a maximum and back to minimum within the space of a few months, remaining bright only for a week or so.

R Coronae Borealis-type Stars: R Coronae Borealis itself was at normal maximum, a phase attained early in 1940, after having gone through a series of spectacular variations in 1938-39. S Apodis remained at maximum throughout the year. Six years have elapsed since the last observed minimum. SU Tauri was at maximum, around magnitude 9.5, but with considerable more scatter in the estimates than usual. The last observed minimum of this star occurred in 1938.

RY Sagittarii, at maximum since late in 1939, has varied, approximately in the short-term period previously pointed out by Dr. L. Jacchia.

SS Cygni-type Stars: For the first time in the forty-five years since the discovery of SS Cygni, the 1941 winter maximum of SS Cygni passed unobserved, as far as the A.A.V.S.O. observers were concerned. It is to be hoped that observers in Denmark may have noted the maximum of last February or March. However, five maxima were very completely observed during the past year, one each in October and December of 1940, and May, June, and August of 1941.

Not a single maximum of U Geminorum was observed with certainty during

the year. Doubtless several occurred, but at times when cloudy conditions prevailed, or the star was in close promimity to the sun. For SS Aurigae, there were four observed maxima, one each in November, 1940, and in January, March, and August, 1941. RU Pegasi has presented three maxima, one each in January, May, and July. For SU Ursae Majoris there were indications of at least three maxima, two in March, of the narrow type, and a long maximum in April. For UV Persei, there was only one well-authenticated maximum observed, that of August, 1941.

Z Camelopardalis-type Stars: Z Camelopardalis itself has been very closely followed in the past year. Eleven maxima were observed at a mean interval of 29.6 days. The intervals between maxima varied between 21 and 45 days, the 45-day interval being almost unprecedented. RX Andromedae has behaved in a very unusual manner throughout the entire year. Until August the star fluctuated in an apparently haphazard manner through a very small amplitude, around magnitude 11.7, while during August and September it varied between magnitudes 11.6 and 12.9 in a mean cycle of about 8 to 10 days. Curiously enough, the star has not varied through its usual amplitude of two and a half magnitudes since September, 1939. Perhaps, after the interval of comparative quiescence, these short-term cycles may be the precursor of the resumption of normal amplitude and length of cycle. In view of the fact that the star is rather far north, and, accordingly, well placed for almost continuous observation, it is hoped that a daily record of the activities of this interesting star may be secured. AB Draconis, although usually faint, requires much closer attention than has been given to it in the past year, if we are to follow its variations with any degree of certainty.

Z Andromedae: In the "Notes" for October attention was called to the latest increase in brightness of Z Andromedae, when the star, having decreased to nearly the tenth magnitude, rose again to magnitude 8.5. The maximum was indicated in August, and since then the star has gradually decreased to about the ninth magnitude. This is a highly important star and observations of brightness are urgently needed to correlate the light variations with the spectral variations.

S Persei: Another interesting variable with, perhaps, interrelated periods is the star S Persei; see these notes for May, 1939. Sometimes the star varies through a large amplitude, again through a comparatively small amplitude. For several years past the small amplitude has prevailed, whereas during the previous few years the large amplitude has been prevalent. The recently observed minimum is the faintest since that observed in 1925, and the maximum magnitude also appears to be the brightest since that year.

V Hydrae: The N-type variable V Hydrae, which was the first star for which both a short- and long-term period was noted—530 days and 18 years, respectively —appears to be fulfilling the expectations that another 18-year cycle would be completed in 1942 or 1943. The star appears to be attaining a fainter magnitude at each successive short-term interval, and during the year was recorded as faint as visual magnitude 10.4. In 1925 it had dropped to the twelfth magnitude.

R Aquarii: The long-period variable R Aquarii, which during the years 1922 to 1937 passed through a series of marked deviations from normal activity,—see these notes for January, 1937—presented a perfectly normal form of light curve, varying between magnitudes 6.9 and 11.3 during the past year. This condition may continue for many cycles, but we should be constantly on the lookout for another abnormal interval.

V Sagittae: The irregular variable V Sagittae, whose light changes can never be predicted, gradually increased in brightness from magnitude 12.2 to 10.5, and

then, with marked fluctuation in between, decreased to magnitude 12.8 at the end of the year. An interval of approximately 300 days appears to have been indicated between the last two maximum phases. The possibility that V Sagittae may be the remnants of an old nova is not precluded, when we glance at the light curve of the past ten years.

RR Tauri: This star, with characteristics of light curve not dissimilar to those of V Sagittae, has varied irregularly and with decidedly changeable amplitudes. However, the differences in spectra do not place RR Tauri and V Sagittae in the same category. Before conjunction with the sun, RR Tauri varied between magnitudes 11.0 and 12.5, and since then, between magnitudes 10.5 and 11.7.

R Hydrae: The long-period variable R Hydrae, for which a gradual shortening of period has been well established, still presents evidence of the shorter period, now around 400 days, whereas the length of period at the end of the 17th century was about 500 days.

R Scuti: Always of interest because of its unpredictable activities, R Scuti proves to be one of the best observed of the semi-regular variables. Minima, which reached the seventh magnitude, were observed in October, 1940, and July, 1941, and it is probable that one minimum escaped observation half way in between.

o Ceti: Mira Ceti attained a maximum magnitude of 3.6 in 1941, quite consistent with what was expected when we find that the probable interval between the attainment of magnitude 6.0 on the increasing branch of the curve between the last two maxima was about 340 days, the average period being 331.6 days.

χ Cygni: This large-range variable presented a rise to maximum almost identical with that of the previous maximum, a slight wave in the curve between magnitudes 10.0 and 9.0, rather than a definite still-stand. The magnitude reached during the last four maxima has averaged 5.3, with very little scatter.

One could mention many other variables which have presented interesting features, but space does not permit.

The Annual Summary of Observations: The following table presents the monthly and yearly totals of observations submitted by those observers who made fifty or more estimates of variables. Those marked with an asterisk (*) are the foreign observers, of whom there are 16 in number.

ANNUAL REPORT OF THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS FOR THE YEAR ENDING SEPTEMBER, 1941

Observer	October	November	December	January	February	March	April	May	June	July	August	September	Total
Ahnert*	..	374	..	..	..	..	..	..	..	..	..	..	374
Albrecht . . .	41	83	18	..	..	12	24	8	..	17	..	20	223
Baldwin* ...	134	..	41	..	..	..	..	..	..	..	..	..	175
Ball, A. R. .	49	30	..	..	9	11	44	7	45	19	43	65	322
Ball, J.	36	21	52	13	..	26	..	35	73	39	48	12	355
Bappu*	68	..	..	..	67	61	..	65	..	..	..	..	261
Blunck	75	43	9	11	16	11	19	..	37	34	51	53	359
Bouton	95	90	54	49	45	29	57	81	104	38	55	50	747
Brocchi	20	44	..	..	20	22	10	18	..	13	..	11	158
Buckstaff ...	145	30	18	..	..	11	..	20	9	13	34	54	333
Carpenter ..	22	9	..	..	..	..	8	..	..	..	..	28	67
Cave	..	..	..	4	..	16	46	29	20	7	9	8	139
Chandra* ...	..	..	..	..	..	..	..	261	257	76	350	..	944
Cilley	103	208	154	155	53	52	104	100	..	202	102	104	1337

Observer	October	November	December	January	February	March	April	May	June	July	August	September	Total
Cooke	25	22	..	..	..	..	..	..	..	18	..	..	65
Cousins* ...	150	100	150	50	50	99	102	..	150	155	151	350	1507
Dafter*	11	..	25	16	..	..	48	..	22	20	50	26	218
Diedrich ...	19	10	18	5	7	7	19	6	37	1	4	10	143
Escalante* .	97	89	98	175	83	88	..	39	..	17	..	..	686
Fernald	375	275	112	158	150	161	204	283	303	205	442	485	3153
Ford	3	..	..	..	7	9	10	..	23	..	39	7	98
Franklin ...	..	..	..	26	13	14	..	35	24	..	..	24	136
Gillespie ...	..	..	..	..	..	..	..	..	16	24	11	..	51
Gregory ...	109	..	..	..	..	..	..	..	..	..	..	..	109
Griffin	33	42	7	52	40	48	30	36	22	42	7	39	398
Halbach ...	54	127	11	..	1	39	101	152	53	128	69	276	1011
Harris	37	13	12	11	35	54	36	25	24	39	22	40	348
Hart	..	..	..	..	..	..	..	15	..	43	..	54	112
Hartmann ..	201	275	219	173	187	144	173	171	149	134	62	20	1908
Hiett	40	..	26	..	14	..	..	15	..	23	..	20	138
Hildom	29	4	..	..	2	15	24	2	25	..	18	..	119
Holt	77	..	298	299	234	255	323	344	249	..	128	245	2452
Houghton* .	..	..	..	..	68	69	130	129	75	..	..	..	471
Howarth* ..	..	15	10	21	..	14	18	..	25	18	16	14	151
Irland	7	19	..	12	..	19	16	..	..	..	..	..	73
Jones	270	107	87	136	..	41	..	7	..	146	262	334	1390
Kearons ...	111	147	136	102	173	161	175	160	105	100	124	200	1694
Kelly	25	16	23	17	20	18	20	15	18	13	16	19	220
deKock*	..	243	240	444	..	269	534	..	210	272	52	347	2611
Kotsakis* ...	..	82	..	..	..	..	..	..	..	..	..	..	82
Koutz	..	62	..	15	24	10	59	80	190	..	..	..	440
Livingston .	61	43	53	6	13	..	57	82	41	27	52	119	554
Loreta*	1800	..	..	..	..	..	..	..	..	..	..	..	1800
Lovinus	27	10	14	..	8	6	..	5	..	24	14	22	130
Manlin	15	..	..	..	..	..	38	..	62	..	82	64	261
Mason	35	..	18	23	36	21	17	5	..	..	..	..	155
Maupomé* .	76	40	48	49	50	44	62	55	..	18	15	36	493
Millard	..	..	..	..	..	18	..	32	..	..	..	..	50
Nadeau* ...	..	26	..	6	10	3	9	..	33	35	50	41	213
Parker	17	23	13	10	16	15	19	27	42	15	..	..	197
Parks	24	32	43	38	44	29	42	35	36	49	49	69	490
Peltier	175	179	148	94	67	129	178	204	153	178	207	277	1989
Prinslow ...	5	5	7	5	4	2	7	3	9	5	34	..	86
Purdy	8	8	8	8	8	8	5	..	..	..	..	..	53
Rosebrugh ..	109	112	59	51	38	39	36	40	34	51	43	61	673
deRoy*	..	..	60	..	..	36	41	50	23	..	5	..	215
Ryder	17	17	13	..	..	..	..	3	..	7	..	8	65
Saxon	44	40	48	6	13	..	61	97	64	37	37	97	544
Schoenke ...	12	8	22	16	18	3	31	4	31	13	61	75	294
Sill	80	57	51	17	34	11	51	26	10	54	12	37	440
Smart	..	2	..	..	..	..	7	63	110	73	22	..	277
Smith, F. P..	8	18	5	10	4	5	12	12	14	6	8	13	115
Stahr	14	3	5	3	4	17	11	..	13	21	24	..	115
Taulman ...	15	..	..	41	..	58	49	35	..	..	54	101	353
Topham* ...	72	145	43	10	14	70	135	38	22	28	27	40	644
Walton	13	38	..	..	8	..	17	20	..	..	..	..	96
Webb	51	44	26	14	22	22	..	12	40	8	11	23	273
Wilson	..	..	..	..	..	..	..	..	9	31	25	11	76
Yamasaki* ..	20	41	20	47	..	..	49	36	31	..	..	..	244
54 others ...	197	190	40	47	12	29	48	83	61	59	96	105	967
													37444

The Prager History and Bibliography of Variable Stars: Dr. Richard Prager has recently completed his supplementary volume of the history and bibliography of stars recognized as variable during the years 1931-1938. The number of entries totals 3,592. This publication is an extension of the work begun some years ago at the Berlin-Babelsberg Observatory. The stars are listed by constellations, and the data include name, provisional designations, year and place of discovery, probable type of variation, period, and epoch of maximum and minimum. Copious notes are given in the remarks. There are several valuable appendices, including reference to publications where light curves, charts, and sequences may be found. The volume—Harvard Annals III—should prove of great value to all variable-star investigators.

Observers and Observations received during October, 1941:

Observer	Var.	Obs	Observer	Var.	Obs.
Albrecht	28	38	Leavitt	9	9
Ball, A. R.	30	75	Livingston	2	2
Ball, J.	19	24	Lovinus	9	9
Blunck	43	51	Lange	9	13
Bouton	39	53	Manlin	54	63
Brocchi	11	11	Mason	19	40
Buckstaff	16	51	Maupomé	9	9
Cilley	95	309	McKeon	1	5
Cousins	76	251	Nadeau	31	57
Dafter, Mrs.	7	14	Oleson	4	4
Fernald	249	543	Parker	21	21
Ford	10	10	Parks	28	58
Gaebler	3	3	Peltier	156	240
Giese	21	26	Reeves	3	5
Griffin	18	19	Rosebrugh	14	126
Halbach	99	130	Ryder	11	11
Harris	31	31	Saxon	3	3
Hartmann	76	79	Schoenke	30	36
Hayner	3	5	Sill	33	33
Hildom	18	18	Smith	11	14
Holt	173	255	Topham	17	17
Houghton	47	47	Townsend	7	7
Howarth	11	11	Toyek	16	17
Jones	100	266	Webb	19	20
Kearons, Mrs.	99	232	Weber	37	37
Kelly	12	17	Wilson	11	23
Kerns	1	1	Yamasaki	30	47
Koons	83	106			
				55 Totals	3602

November 14, 1941.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

In the November POPULAR ASTRONOMY, p. 500, H. H. Nininger called attention to a large number of brilliant meteors reported to him in the interval from August 29 to September 8. This suggested looking over our A.M.S. files and I find 10 fireballs for the interval August 29 to September 10, inclusive. As we average about 7 reports per 13 days, the difference is not excessive. But the search brought out some things which were worth noting. On 1941 January 21/22,

four fireballs were reported. Using U.T. these were on January 22 as follows: Maryland 3:03; New York 4:10; Arizona 5:30; off eastern shore of Virginia 8:14—in other words all within just over 5 hours. On June 21/22 (June 22 U.T.), off the west coast of Mexico, three were observed at U.T. 10:48, 11:54, and 11:55; another in Texas next day at 4:00, or four within 15 hours. As no showers were known to be going on, both cases are striking. I have not yet attempted to work up possible radiants from these groups. More spectacular was the display on October 22/23. Again using U.T., we have October 23: Washington, D. C., 0:26; Milton, Maine, 0:11, 2:35, 2:50, 3:13, and 4.43; Elsmere, N. Y., 2:39. Possibly the last is a duplicate of the second or third seen in Maine. Most of these are, indeed, probably Orionids. Unfortunately, reports on this shower have been unusually slow in arriving, assuming of course that they were made. It is plain, however, that on October 22/23 fireballs were numerous. The A.M.S. manages to get from 200 to 300 fireballs reported to it annually. This is but a tiny fraction of those seen over America, and, indeed, observations at sea account for a large part of these.

The Eta Aquarid shower is another important one much neglected by our members. From a ship (the name is no longer published due to the war) at λ 126° 20′ W, ϕ 31° 26′ N, on 1941 May 2/3 from 11:00 to 12:00 G.C.T. (May 3) 23 meteors were seen, 5 being described, and leaving trains which lasted from 5 to 25 seconds. On May 3/4 at 6:56 G.C.T. (May 4), λ 50° 57′ W, ϕ 5° 36′ N, from another ship, a splendid Aquarid fireball was seen almost head-on and leaving a fine train (exact duration not given but from description probably fully a minute). The observer says that: ". . . during the succeeding hour an unusually large number of meteors were observed which appeared in the same direction but at a lower altitude . . ." A fine Aquarid fireball was seen the same morning at Columbus, Ohio, by W. H. Haas at 12:58 G.C.T.; another fine one from a ship at λ 77° 14′ W, ϕ 32° 32′ N, at 07:46. The earlier A.M.S. reports on this shower appeared in the June and October "Meteor Notes," pages 324 and 438, respectively. Again, it is inexplicable why our observers do not make more efforts to observe on nights, when they know something specially good can be gotten from their work.

In the October "Meteor Notes" I mentioned the Delta Aquarid observations made by the groups from the A.A.F.I. in Philadelphia, and on page 438 may be found their rates. Miss Edith Reilly, a graduate student majoring in astronomy here, has worked out the five probable coincidences. Of these, four beginning and five ending points come within the limits of error we impose. They are:

1941 July 27/28 E.S.T.	Magn.	Beg. Height km		End. Height km		Stations
12 52	4	128.3 ± 39.6		95.8 ± 30.6		1, 2, 3
13 23	—			109.1	20.5	2, 3
13 52	2	75.9	7.0	59.4	5.8	1, 3
13 58	2	203.2	5.3	129.4	14.5	1, 2
14 48	2	89.1	8.6	62.7	6.7	1, 2
Average		124.1 ± 15.1		91.3 ± 19.6		

None of the meteors came from the Delta Aquarid radiant. The great differences in the individual heights must be due largely to errors of plotting, but the average heights for the group seem reasonable. The large deviations from the mean for the first meteor probably came, in part, from having to use only the altitudes for the solution for Stations 1-3 as the meteor moved almost in the

plane containing these two stations. The groups at Stations 2 and 3 did not estimate their magnitudes, an omission in which there has been reformation in later reports from these same groups. The three stations were at the vertices of an approximately equilateral triangle, with sides about 30′ long.

A table containing some radiants derived from recent work now follows. I confess that the more I work on meteors the less confidence I have in tables of minor radiants. Perhaps the true solution of the question will be to accept as real only those which can be detected with certainty every year, or at recurrent returns after the same number of years have elapsed. Meantime, however, I believe that the publication of lists, carefully derived, lays the foundation for future selection of those radiants which will stand the test and are thus justified.

RADIANTS

A.M.S. No.		Date	α	δ	No. Meteors	Accuracy	Observer
4051	1940	Sept. 8	26	+19	4	G	M. A. D. Khan
4052		Sept. 8	61	— 3	6-7	G	"
4053		Sept. 9	50	+13	5	G	"
4054		Sept. 9	75	— 7	5	G	"
4055		Dec. 13	110	+12	3	G	"
4056		Dec. 26	120	+47	6	G	"
4057		Dec. 27	144	+13	7-10	VG	"
4058		Dec. 27	182.5	+17	10	G	"
4059		Dec. 28	153	—31	7-10	G	"
4060		Dec. 29	171	+31	6+	G	"
4104	1941	Aug. 9.8	43	+54	10±	F	J. Metzner
4105		Aug. 10.7	44	+55	11+	G	"
4106		Aug. 10.7	47	+15	4	F	"
4107		Sept. 23.7	7	+54	4	G	C. Tapscott
4108		Aug. 15.7	39	+47	4	G	W. A. Borden
4109		Aug. 15.7	319	+51	4	G	"
4110		Aug. 16.7	349	+58	5	G	A.A.F.I.
4111		Aug. 16.7	22	+78	7—	G	"
4112		Aug. 16.7	84	+68	7+	G	"
4113		Aug. 16.7	59.5	+ 3.5	5	VG	"
4114		Aug. 16.7	310	+23	5	G	"

Two books dealing largely with meteors have recently appeared. They are: "Luminosity of Meteors and Comets" by Elliott Smith, and "Between the Planets" by Fletcher G. Watson. I hope to review certain sections of both at some length in these "Notes."

1941 November 15, Flower Observatory, Upper Darby, Pennsylvania.

Daylight Meteor

On October 28, at about 1:30 P.M., I was on University Avenue in Chicago, east of Eckhart Hall, on the campus of the University of Chicago, and saw a meteor flash into view, gain in brilliance, and finally explode. Its direction was about 18° east of due north, and it seemed to make an angle of about 35° to the horizon. The trail was very brilliant, particularly at the terminal end, even though the sun was shining. There was a slight trail of smoke left afterwards which drifted away in about half an hour.

GEORGE S. MONK.

University of Chicago, October 29, 1941.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
Department of Astronomy, University of California, Los Angeles

President of the Society: LINCOLN LA PAZ, Department of Mathematics, Ohio State University, Columbus

Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, Los Angeles, and Department of Astronomy, University of Southern California, Los Angeles

Statistical Studies of the Meteoritic Falls of the World: 3. Their Time Distribution*

By FREDERICK C. LEONARD *with* BORIS SLANIN

ABSTRACT

This paper contains a study of all the authentic meteoritic falls of the world, 1314 in number (21 of date earlier than 1790 and 1293 of date 1790 and later), for which reasonably reliable information concerning the time of fall or find is available. By means of a series of tables and graphs, the following subjects are treated: (1) the observed falls by years; (2) the unobserved falls by years; (3) both kinds of falls by years; (4) the observed falls by months; and (5) the observed falls by hours. The average numbers of falls for the decade 1930-39 are compared with the corresponding numbers for the 150-year interval 1790-1939. The general increase in meteoritical activity, particularly since 1920, is apparent from the material of the paper.

The results of a study of the time distribution of meteoritic falls are presented best by means of a series of tables and graphs and when so presented are practically self-explanatory. Hence this paper consists largely of a number of tables and their concomitant diagrams. Table 1 exhibits the distribution of the observed falls by years from 1790 to 1940.[1] The first column lists the year; the second and third, the number of aërolitic (*A.*) falls and the number of (combined) sideritic and siderolitic (*S.*) falls, respectively, for the eastern hemisphere;[2] the fourth and fifth, the same variety of information for the western hemisphere; and the sixth, seventh, and eighth, the statistics for the entire world. The data in the eighth column (headed *T.*) are the sums of the numbers in the sixth and seventh columns. The totals for the 150-year interval are contained in the last line of the table. In Fig. 1, the totals from column *T.* of the table are plotted as ordinates against the corresponding years as abscissas.

Table 2 and Fig. 2, for the unobserved falls, and Table 3 and Fig. 3, for both kinds of falls together, have been constructed exactly like Table 1 and Fig. 1 (except that in Table 3 the values of *A.*, *S.*, and *T.* for the world only are listed) and call for no further explanation.

In Table 4, "The Distribution of Observed Falls by Months and Days," the first column gives the day of the month and an argument "*N.D.*," meaning "No Day," that is provided for the tabulation of all falls for which only the year and

*Read at the Eighth Meeting, Flagstaff, Arizona, 1941 June 23-25. "Studies: 2. Their Areal Concentration" appeared in *C.S.R.M.*, **2**, No. 4, 262-9; *P.A.*, **49**, 206-14, 1941.

TABLE 1

THE DISTRIBUTION OF OBSERVED FALLS BY YEARS FROM 1790 TO 1940

	E. Hem.		W. Hem.		World				E. Hem.		W. Hem.		World				E. Hem.		W. Hem.		World				E. Hem.		W. Hem.		World		
Year	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*T.*	Year	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*T.*	Year	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*T.*	Year	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*T.*
1790	1	—	—	—	1	—	1	1829	1	—	2	—	3	—	3	1868	8	1	2	—	10	1	11	1907	3	—	1	—	4	—	4
91	—	—	—	—	—	—	—	1830	2	—	—	—	2	—	2	69	4	—	2	—	6	—	6	08	4	1	1	—	5	1	6
92	—	—	—	—	—	—	—	31	2	—	—	—	2	—	2	1870	2	1	—	—	2	1	3	09	1	—	1	—	2	—	2
93	—	—	—	—	—	—	—	32	—	—	—	—	—	—	—	71	3	—	1	—	4	—	4	1910	7	1	1	—	8	1	9
94	1	—	—	—	1	—	1	33	1	—	—	—	1	—	1	72	4	—	—	—	4	—	4	11	3	—	1	—	4	—	4
1795	2	—	—	—	2	—	2	34	2	—	—	—	2	—	2	73	3	—	1	—	4	—	4	12	1	1	1	—	2	1	3
96	2	—	—	—	2	—	2	1835	3	—	—	1	3	1	4	74	2	—	1	—	3	—	3	13	1	1	1	—	2	1	3
97	—	—	—	—	—	—	—	36	1	—	1	—	2	—	2	1875	5	—	1	—	6	—	6	14	5	—	—	—	5	—	5
98	2	—	—	—	2	—	2	37	3	—	—	—	3	—	3	76	3	1	1	—	4	1	5	1915	2	—	—	1	2	1	3
99	—	—	—	—	—	—	—	38	5	—	—	—	5	—	5	77	5	—	2	—	7	—	7	16	6	2	1	—	7	2	9
1800	—	—	—	—	—	—	—	39	—	—	1	—	1	—	1	78	5	—	1	—	6	—	6	17	5	1	2	—	7	1	8
01	1	—	—	—	1	—	1	1840	3	—	—	—	3	—	3	79	3	—	3	1	6	1	7	18	5	—	1	1	6	1	7
02	—	—	—	—	—	—	—	41	3	—	—	—	3	—	3	1880	2	1	—	—	2	1	3	19	2	—	2	—	4	—	4
03	3	—	—	—	3	—	3	42	3	2	—	—	3	2	5	81	3	1	1	—	4	1	5	1920	4	1	—	—	4	1	5
04	1	—	1	—	2	—	2	43	5	—	1	—	6	—	6	82	4	—	—	—	4	—	4	21	4	1	2	1	6	2	8
1805	3	—	—	—	3	—	3	44	2	—	1	—	3	—	3	83	3	—	—	—	3	—	3	22	2	—	2	—	4	—	4
06	1	—	—	—	1	—	1	1845	2	—	—	—	2	—	2	84	3	—	—	—	3	—	3	23	3	—	1	—	4	—	4
07	1	—	1	—	2	—	2	46	2	—	1	—	3	—	3	1885	3	—	—	1	3	1	4	24	6	—	4	—	10	—	10
08	4	—	—	—	4	—	4	47	—	1	1	—	1	1	2	86	5	—	—	1	5	1	6	1925	6	—	2	1	8	1	9
09	1	—	—	—	1	—	1	48	3	—	1	—	4	—	4	87	5	—	1	—	6	—	6	26	6	—	—	—	6	—	6
1810	2	—	—	—	2	—	2	49	—	—	1	—	1	—	1	88	—	—	1	—	1	—	1	27	5	2	1	—	6	2	8
11	2	—	—	—	2	—	2	1850	2	—	—	—	2	—	2	89	4	—	1	—	5	—	5	28	5	—	1	—	6	—	6
12	4	—	—	—	4	—	4	51	3	—	—	—	3	—	3	1890	5	—	2	—	7	—	7	29	6	—	2	—	8	—	8
13	2	—	—	—	2	—	2	52	4	—	—	—	4	—	4	91	2	—	—	—	2	—	2	1930	6	—	3	—	9	—	9
14	4	—	—	—	4	—	4	53	3	—	—	—	3	—	3	92	1	—	2	—	3	—	3	31	3	—	—	—	3	—	3
1815	2	—	—	—	2	—	2	54	1	—	—	—	1	—	1	93	2	—	2	—	4	—	4	32	6	—	2	—	8	—	8
16	—	—	—	—	—	—	—	1855	3	—	1	—	4	—	4	94	3	—	1	—	4	—	4	33	8	2	5	—	13	2	15
17	—	—	—	—	—	—	—	56	2	—	—	—	2	—	2	1895	3	—	—	—	3	—	3	34	4	2	2	—	6	2	8
18	3	—	—	—	3	—	3	57	5	—	1	—	6	—	6	96	2	—	2	—	4	—	4	1935	3	5	—	—	3	5	8
19	2	—	—	—	2	—	2	58	4	—	—	—	4	—	4	97	8	—	—	—	8	—	8	36	4	—	1	—	5	—	5
1820	1	—	—	—	1	—	1	59	2	—	2	—	4	—	4	98	1	1	2	1	3	2	5	37	3	—	—	—	3	—	3
21	1	—	—	—	1	—	1	1860	4	1	1	—	5	1	6	99	4	1	1	—	5	1	6	38	5	—	3	—	8	—	8
22	5	—	—	—	5	—	5	61	3	—	—	—	3	—	3	1900	4	1	1	—	5	1	6	39	1	—	4	—	5	—	5
23	1	—	1	—	2	—	2	62	2	—	—	—	2	—	2	01	4	—	—	—	4	—	4	1940	—	—	—	—	—	—	—
24	3	—	—	—	3	—	3	63	6	—	—	—	6	—	6	02	4	1	1	—	5	1	6								
1825	—	—	2	—	2	—	2	64	3	—	—	—	3	—	3	03	4	1	2	—	6	1	7	Total	433	36	113	9	546	45	591
26	2	—	—	—	2	—	2	1865	6	—	1	—	7	—	7	04	3	2	1	—	4	2	6								
27	2	—	1	—	3	—	3	66	6	—	—	—	6	—	6	1905	4	—	1	—	5	—	5								
1828	—	—	1	—	1	—	1	1867	3	—	—	—	3	—	3	1906	4	—	2	—	6	—	6								

TABLE 2

THE DISTRIBUTION OF UNOBSERVED FALLS BY YEARS FROM 1790 TO 1940

	E. Hem.		W. Hem.		World				E. Hem.		W. Hem.		World				E. Hem.		W. Hem.		World				E. Hem.		W. Hem.		World		
Year	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*T.*	Year	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*T.*	Year	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*T.*	Year	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*T.*
1790	—	—	—	—	—	—	—	1829	—	—	—	—	—	—	—	1868	—	—	—	—	—	—	—	1907	—	—	—	—	—	—	—
91	—	—	—	—	—	—	—	1830	—	—	—	—	—	—	—	69	—	—	—	—	—	—	—	08	—	—	—	—	—	—	—
92	—	—	—	—	—	—	—	31	—	—	—	—	—	—	—	1870	—	—	—	—	—	—	—	09	—	—	—	—	—	—	—
93	—	—	—	—	—	—	—	32	—	—	—	—	—	—	—	71	—	—	—	—	—	—	—	1910	—	—	—	—	—	—	—
94	—	—	—	—	—	—	—	33	—	—	—	—	—	—	—	72	—	—	—	—	—	—	—	11	—	—	—	—	—	—	—
1795	—	—	—	—	—	—	—	34	—	—	—	—	—	—	—	73	—	—	—	—	—	—	—	12	—	—	—	—	—	—	—
96	—	—	—	—	—	—	—	1835	—	—	—	—	—	—	—	74	—	—	—	—	—	—	—	13	—	—	—	—	—	—	—
97	—	—	—	—	—	—	—	36	—	—	—	—	—	—	—	1875	—	—	—	—	—	—	—	14	—	—	—	—	—	—	—
98	—	—	—	—	—	—	—	37	—	—	—	—	—	—	—	76	—	—	—	—	—	—	—	1915	—	—	—	—	—	—	—
99	—	—	—	—	—	—	—	38	—	—	—	—	—	—	—	77	—	—	—	—	—	—	—	16	—	—	—	—	—	—	—
1800	—	—	—	—	—	—	—	39	—	—	—	—	—	—	—	78	—	—	—	—	—	—	—	17	—	—	—	—	—	—	—
01	—	—	—	—	—	—	—	1840	—	—	—	—	—	—	—	79	—	—	—	—	—	—	—	18	—	—	—	—	—	—	—
02	—	—	—	—	—	—	—	41	—	—	—	—	—	—	—	1880	—	—	—	—	—	—	—	19	—	—	—	—	—	—	—
03	—	—	—	—	—	—	—	42	—	—	—	—	—	—	—	81	—	—	—	—	—	—	—	1920	—	—	—	—	—	—	—
04	—	—	—	—	—	—	—	43	—	—	—	—	—	—	—	82	—	—	—	—	—	—	—	21	—	—	—	—	—	—	—
1805	—	—	—	—	—	—	—	44	—	—	—	—	—	—	—	83	—	—	—	—	—	—	—	22	—	—	—	—	—	—	—
06	—	—	—	—	—	—	—	1845	—	—	—	—	—	—	—	84	—	—	—	—	—	—	—	23	—	—	—	—	—	—	—
07	—	—	—	—	—	—	—	46	—	—	—	—	—	—	—	1885	—	—	—	—	—	—	—	24	—	—	—	—	—	—	—
08	—	—	—	—	—	—	—	47	—	—	—	—	—	—	—	86	—	—	—	—	—	—	—	1925	—	—	—	—	—	—	—
09	—	—	—	—	—	—	—	48	—	—	—	—	—	—	—	87	—	—	—	—	—	—	—	26	—	—	—	—	—	—	—
1810	—	—	—	—	—	—	—	49	—	—	—	—	—	—	—	88	—	—	—	—	—	—	—	27	—	—	—	—	—	—	—
11	—	—	—	—	—	—	—	1850	—	—	—	—	—	—	—	89	—	—	—	—	—	—	—	28	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	51	—	—	—	—	—	—	—	1890	—	—	—	—	—	—	—	29	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—	52	—	—	—	—	—	—	—	91	—	—	—	—	—	—	—	1930	—	—	—	—	—	—	—
14	—	—	—	—	—	—	—	53	—	—	—	—	—	—	—	92	—	—	—	—	—	—	—	31	—	—	—	—	—	—	—
1815	—	—	—	—	—	—	—	54	—	—	—	—	—	—	—	93	—	—	—	—	—	—	—	32	—	—	—	—	—	—	—
16	—	—	—	—	—	—	—	1855	—	—	—	—	—	—	—	94	—	—	—	—	—	—	—	33	—	—	—	—	—	—	—
17	—	—	—	—	—	—	—	56	—	—	—	—	—	—	—	1895	—	—	—	—	—	—	—	34	—	—	—	—	—	—	—
18	—	—	—	—	—	—	—	57	—	—	—	—	—	—	—	96	—	—	—	—	—	—	—	1935	—	—	—	—	—	—	—
19	—	—	—	—	—	—	—	58	—	—	—	—	—	—	—	97	—	—	—	—	—	—	—	36	—	—	—	—	—	—	—
1820	—	—	—	—	—	—	—	59	—	—	—	—	—	—	—	98	—	—	—	—	—	—	—	37	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—	1860	—	—	—	—	—	—	—	99	—	—	—	—	—	—	—	38	—	—	—	—	—	—	—
22	—	—	—	—	—	—	—	61	—	—	—	—	—	—	—	1900	—	—	—	—	—	—	—	39	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	62	—	—	—	—	—	—	—	01	—	—	—	—	—	—	—	1940	—	—	—	—	—	—	—
24	—	—	—	—	—	—	—	63	—	—	—	—	—	—	—	02	—	—	—	—	—	—	—								
1825	—	—	—	—	—	—	—	64	—	—	—	—	—	—	—	03	—	—	—	—	—	—	—	Total	—	—	—	—	—	—	—
26	—	—	—	—	—	—	—	1865	—	—	—	—	—	—	—	04	—	—	—	—	—	—	—								
27	—	—	—	—	—	—	—	66	—	—	—	—	—	—	—	1905	—	—	—	—	—	—	—								
1828	—	—	—	—	—	—	—	1867	—	—	—	—	—	—	—	1906	—	—	—	—	—	—	—								

Year	E. Hem. A.	E. Hem. S.	W. Hem. A.	W. Hem. S.	World A.	World S.	World T.
27	2	—	1	—	3	—	3
1828	—	—	1	—	1	—	1
66	6	—	—	—	6	—	6
1867	3	—	—	—	3	—	3
1905	4	—	1	—	5	—	5
1906	4	—	2	—	6	—	6

TABLE 2

THE DISTRIBUTION OF UNOBSERVED FALLS BY YEARS FROM 1790 TO 1940

Year	E. Hem. A.	E. Hem. S.	W. Hem. A.	W. Hem. S.	World A.	World S.	World T.
1790	—	—	—	—	—	—	—
91	—	—	—	—	—	—	—
92	—	—	—	1	—	1	1
93	—	1	—	—	—	1	1
94	—	—	—	—	—	—	—
1795	—	—	—	—	—	—	—
96	—	—	—	—	—	—	—
97	—	1	—	—	—	1	1
98	—	—	—	—	—	—	—
99	—	—	—	—	—	—	—
1800	—	—	—	—	—	—	—
01	—	—	—	—	—	—	—
02	—	1	—	—	—	1	1
03	—	—	—	—	—	—	—
04	1	—	—	2	1	2	3
1805	—	—	—	—	—	—	—
06	—	—	—	—	—	—	—
07	—	—	—	—	—	—	—
08	1	—	—	1	1	1	2
09	—	—	—	—	—	—	—
1810	—	1	—	1	—	2	2
11	—	1	—	1	—	2	2
12	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—
14	—	1	—	—	—	1	1
1815	—	—	—	—	—	—	—
16	—	—	—	—	—	—	—
17	—	—	—	—	—	—	—
18	—	—	—	2	—	2	2
19	—	—	—	1	—	1	1
1820	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—
22	1	—	—	1	1	1	2
23	—	—	—	—	—	—	—
24	—	—	—	—	—	—	—
1825	—	—	—	1	—	1	1
26	—	—	—	—	—	—	—
27	—	—	—	—	—	—	—
1828	—	1	—	—	—	1	1
29	—	1	—	—	—	1	1
1830	—	—	—	—	—	—	—
31	—	—	—	—	—	—	—
32	—	—	—	1	—	1	1
33	—	—	—	—	—	—	—
34	—	—	—	—	—	—	—
1835	—	—	—	—	—	—	—
36	—	1	—	1	—	2	2
37	—	—	—	2	—	2	2
38	2	—	—	—	2	—	2
39	—	—	—	4	—	4	4
1840	1	1	—	1	1	2	3
41	—	1	—	—	—	1	1
42	—	1	—	1	—	2	2
43	—	—	—	—	—	—	—
44	—	—	—	1	—	1	1
1845	1	—	—	—	1	—	1
46	1	1	—	2	1	3	4
47	—	2	—	2	—	4	4
48	—	—	—	—	—	—	—
49	—	—	—	—	—	—	—
1850	—	1	—	4	—	5	5
51	—	—	—	1	—	1	1
52	1	—	—	3	1	3	4
53	—	—	—	2	—	2	2
54	—	4	—	5	—	9	9
1855	—	2	—	2	—	4	4
56	—	1	—	4	—	5	5
57	—	1	—	2	—	3	3
58	—	—	—	5	—	5	5
59	—	—	—	2	—	2	2
1860	—	—	—	4	—	4	4
61	—	—	1	1	1	1	2
62	—	—	—	2	—	2	2
63	—	2	1	6	1	8	9
64	2	1	—	—	2	1	3
1865	—	1	—	—	—	1	1
66	—	—	1	3	1	3	4
1867	—	—	—	4	—	4	4
68	2	—	—	4	2	4	6
69	—	—	1	3	1	3	4
1870	—	—	1	1	1	1	2
71	1	—	—	2	1	2	3
72	—	1	—	1	—	2	2
73	—	1	1	2	1	3	4
74	—	1	—	3	—	4	4
1875	—	1	—	4	—	5	5
76	—	2	—	1	—	3	3
77	1	—	—	2	1	2	3
78	—	2	1	1	1	3	4
79	1	—	1	3	2	3	5
1880	—	2	—	5	—	7	7
81	—	—	—	2	—	2	2
82	—	1	—	4	—	5	5
83	2	1	1	4	3	5	8
84	—	2	—	6	—	8	8
1885	—	5	—	4	—	9	9
86	—	4	—	1	—	5	5
87	—	—	5	11	5	11	16
88	1	3	2	5	3	8	11
89	1	1	—	8	1	9	10
1890	1	4	—	4	1	8	9
91	—	2	1	6	1	8	9
92	—	5	1	2	1	7	8
93	—	2	1	4	1	6	7
94	—	1	2	5	2	6	8
1895	—	1	1	3	1	4	5
96	—	—	—	4	—	4	4
97	—	1	2	3	2	4	6
98	1	3	—	7	1	10	11
99	3	1	1	4	4	5	9
1900	1	3	—	2	1	5	6
01	—	—	2	4	2	4	6
02	—	2	—	2	—	4	4
03	—	4	2	10	2	14	16
04	1	3	—	3	1	6	7
1905	2	—	3	1	5	1	6
1906	1	1	2	1	3	2	5
1907	3	1	—	6	3	7	10
08	—	1	1	3	1	4	5
09	1	5	—	2	1	7	8
1910	2	2	1	1	3	3	6
11	1	1	2	1	3	2	5
12	2	2	1	2	3	4	7
13	—	3	1	4	1	7	8
14	1	2	—	2	1	4	5
1915	1	1	2	7	3	8	11
16	1	1	2	2	3	3	6
17	—	1	—	—	—	1	1
18	—	2	3	3	3	5	8
19	1	1	1	2	2	3	5
1920	2	2	—	3	2	5	7
21	—	3	—	4	—	7	7
22	1	1	—	7	1	8	9
23	1	1	2	7	3	8	11
24	—	2	2	2	2	4	6
1925	3	4	1	—	4	4	8
26	—	3	—	1	—	4	4
27	1	1	1	8	2	9	11
28	1	—	5	5	6	5	11
29	1	—	3	4	4	4	8
1930	—	1	1	4	1	5	6
31	1	2	3	7	4	9	13
32	2	4	2	4	4	8	12
33	—	—	9	—	9	—	9
34	—	—	8	3	8	3	11
1935	—	—	8	3	8	3	11
36	2	—	19	3	21	3	24
37	2	6	27	3	29	9	38
38	—	—	15	8	15	8	23
39	—	—	9	1	9	1	10
1940	—	—	5	2	5	2	7
TOTAL	60	141	168	333	228	474	702

the month have been recorded. In the 2 columns under the heading of each month are listed the number of *A.* falls and the number of *S.* falls for each day and for "*N.D.*," respectively. The final line of the table contains the monthly totals for each of the 2 kinds of falls (*A.* and *S.*) for every month of the year.

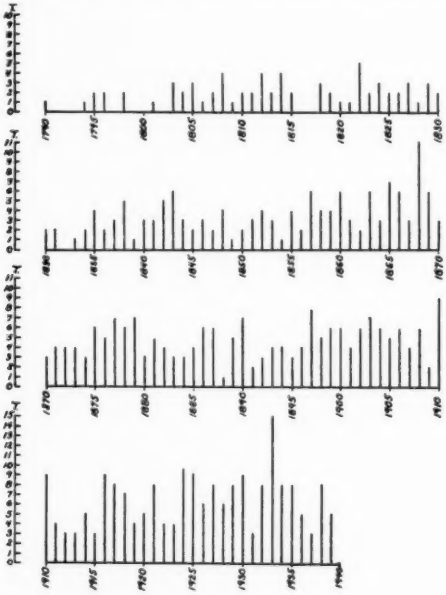


FIGURE 1
OBSERVED FALLS BY YEARS, 1790-1940

In Fig. 4, the totals (*T.*) for *both* varieties of falls (*A.* and *S.*), from the last line of the table, are plotted as ordinates against the corresponding months as abscissas. It is seen that the absolute minimum of the resulting curve (33) occurs in March and a secondary minimum (37) in January, while the absolute maximum (69) occurs in May and secondary maxima (41 and 40) in November and February. Of the 581 falls represented in Table 4 and Fig. 4, 352 took place in the half of the year from April to September, while 229 arrived on the Earth in the 6 months from October to March. The April-to-September falls were, then, more than half again (1.54 times) as numerous as the October-to-March falls. The portion of the curve between March and October, which includes the primary maximum, with its peak in May, is explicable, probably in part at least, as a seasonal effect, attributable to the circumstance that the large majority of the observed falls have been witnessed in the northern hemisphere, where observers are more likely to be out of doors from March to October than from October to March. Whether a cosmic factor also is involved, it is impossible to say.[3]

Table 5 gives the hourly distribution of all the observed falls—469 in number—for which the requisite information is available. The first column tabulates

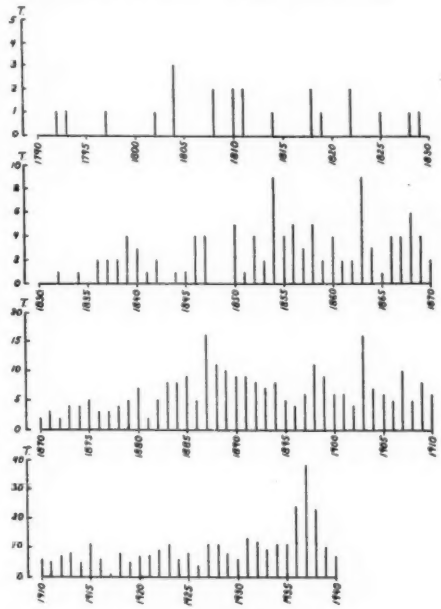


FIGURE 2
UNOBSERVED FALLS BY YEARS, 1790-1940

TABLE 3

THE DISTRIBUTION OF BOTH OBSERVED AND UNOBSERVED FALLS BY YEARS FROM 1790 TO 1940

YEAR	*A.*	*S.*	*T.*	YEAR	*A.*	*S.*	*T.*	YEAR	*A.*	*S.*	*T.*	YEAR	*A.*	*S.*	*T.*
1790	1	—	1	1829	3	1	4	1868	12	5	17	1907	7	7	14
91	—	—	—	1830	2	—	2	69	7	3	10	08	6	5	11
92	—	1	1	31	2	—	2	1870	3	2	5	09	3	7	10
93	—	1	1	32	—	1	1	71	5	2	7	1910	11	4	15
94	1	—	1	33	1	—	1	72	4	2	6	11	7	2	9
1795	2	—	2	34	2	1	3	73	5	3	8	12	5	5	10
96	2	—	2	1835	3	1	4	74	3	4	7	13	3	8	11
97	—	1	1	36	2	2	4	1875	6	5	11	14	6	4	10
98	2	—	2	37	3	2	5	76	4	4	8	1915	5	9	14
99	—	—	—	38	7	—	7	77	8	2	10	16	10	5	15
1800	—	—	—	39	1	4	5	78	7	3	10	17	7	2	9
01	1	—	1	1840	4	2	6	79	8	4	12	18	9	6	15
02	—	1	1	41	3	1	4	1880	2	8	10	19	6	3	9
03	3	—	3	42	3	4	7	81	4	3	7	1920	6	6	12
04	3	2	5	43	6	—	6	82	4	5	9	21	6	9	15
1805	3	—	3	44	3	1	4	83	6	5	11	22	5	8	13
06	1	—	1	1845	3	—	3	84	3	8	11	23	7	8	15
07	2	—	2	46	4	3	7	1885	3	10	13	24	12	4	16
08	5	1	6	47	1	5	6	86	5	6	11	1925	12	5	17
09	1	—	1	48	4	—	4	87	11	11	22	26	6	4	10
1810	2	2	4	49	1	—	1	88	4	8	12	27	8	11	19

TABLE 3—(CONTINUED)

YEAR	*A.*	*S.*	*T.*	YEAR	*A.*	*S.*	*T.*	YEAR	*A.*	*S.*	*T.*	YEAR	*A.*	*S.*	*T.*
1811	2	2	4	1850	2	5	7	1889	6	9	15	1928	12	5	17
12	4	—	4	51	3	1	4	1890	8	8	16	29	12	4	16
13	2	—	2	52	5	3	8	91	3	8	11	1930	10	5	15
14	4	1	5	53	3	2	5	92	4	7	11	31	7	9	16
1815	2	—	2	54	1	9	10	93	5	6	11	32	12	8	20
16	—	—	—	1855	4	4	8	94	6	6	12	33	22	2	24
17	—	—	—	56	2	5	7	1895	4	4	8	34	14	5	19
18	3	2	5	57	6	3	9	96	4	4	8	1935	11	8	19
19	2	1	3	58	4	5	9	97	10	4	14	36	26	3	29
1820	1	—	1	59	4	2	6	98	4	12	16	37	32	9	41
21	1	—	1	1860	5	5	10	99	9	6	15	38	23	8	31
22	6	1	7	61	4	1	5	1900	6	6	12	39	14	1	15
23	2	—	2	62	2	2	4	01	6	4	10	1940	5	2	7
24	3	—	3	63	7	8	15	02	5	5	10		—	—	—
1825	2	1	3	64	5	1	6	03	8	15	23	TOTAL	774	519	1293
26	2	—	2	1865	7	1	8	04	5	8	13				
27	3	—	3	66	7	3	10	1905	10	1	11				
1828	1	1	2	1867	3	4	7	1906	9	2	11				

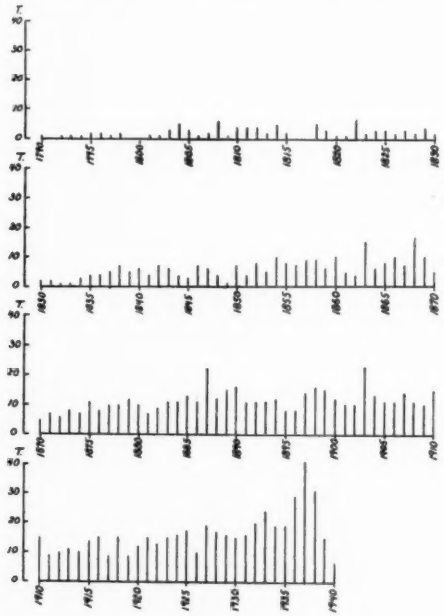


FIGURE 3
ALL FALLS (OBSERVED AND UNOBSERVED) BY YEARS, 1790-1940

the hour; the second, the number of aërolitic (*A.*) falls; the third, the number of (combined) sideritic and siderolitic (*S.*) falls; and the fourth, the total number (*T.*) of both kinds of falls. The final line of the table contains the totals for all 24 hours.[4]

TABLE 4

THE DISTRIBUTION OF OBSERVED FALLS BY MONTHS AND DAYS

Day of Mo.	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sep.		Oct.		Nov.		Dec.	
	A.	*S.*	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*	*A.*	*S.*
1	2	—	2	—	2	—	2	—	2	—	1	1	3	—	1	2	—	—	2	1	1	—	2	—
2	—	—	3	—	—	—	1	—	3	—	3	—	1	—	1	—	1	—	1	—	—	—	2	—
3	2	—	2	—	—	—	1	1	1	—	2	—	2	—	—	—	2	—	2	—	—	—	1	—
4	—	—	—	—	1	—	1	—	—	—	2	—	3	1	2	—	3	—	—	—	2	—	1	—
5	—	—	1	—	—	—	3	—	1	—	—	—	—	—	4	—	4	—	3	—	4	—	1	—
6	—	—	—	—	1	—	3	—	—	—	2	—	1	—	—	—	1	—	1	—	—	—	2	—
7	1	—	—	—	—	—	2	1	—	—	1	—	—	1	3	—	3	—	1	—	—	—	—	—
8	1	—	2	—	—	—	2	—	3	—	1	—	3	—	3	1	1	—	1	—	—	—	—	—
9	1	—	2	—	1	—	4	—	5	1	2	—	1	—	2	—	2	—	1	—	—	—	2	—
10	—	—	3	—	—	—	3	—	—	1	1	—	4	—	2	—	2	—	—	—	—	—	3	—
11	1	—	—	—	—	—	1	—	3	—	2	—	3	—	3	—	1	—	1	—	1	—	—	—
12	2	—	1	—	3	1	1	—	1	—	5	—	4	—	1	—	—	—	2	—	5	—	—	—
13	—	—	2	—	—	—	3	1	2	—	1	—	2	—	1	1	4	—	6	—	1	—	3	—
14	—	—	—	—	1	—	2	—	4	—	1	—	3	1	2	—	1	—	1	—	—	—	1	—
15	2	—	3	—	1	—	2	—	1	—	1	1	2	—	—	—	2	—	3	—	2	—	2	—
16	—	—	3	—	1	—	1	—	—	—	4	—	1	—	3	—	1	—	1	1	1	—	—	—
17	2	—	1	—	1	—	1	—	3	—	2	—	3	2	1	—	2	—	2	—	1	—	—	—
18	1	—	3	—	—	—	1	—	1	—	2	—	1	—	1	—	—	—	1	1	1	—	—	—
19	2	—	2	—	3	—	2	—	3	—	2	—	1	—	—	—	1	—	—	—	2	—	1	—
20	—	—	1	—	2	—	2	2	3	1	4	—	2	—	—	—	1	—	—	—	2	—	—	—
21	2	—	—	—	—	—	1	—	1	—	3	—	—	—	—	—	1	—	2	—	1	—	1	—
22	2	—	—	—	1	—	1	—	4	—	1	—	1	—	1	—	2	—	1	—	1	—	3	—
23	2	1	—	—	—	—	—	—	2	—	—	—	1	1	1	—	3	—	—	—	1	—	1	—
24	1	—	—	—	2	—	1	—	4	—	1	—	3	—	—	—	—	—	1	—	2	—	1	—
25	3	—	1	—	2	—	1	—	—	—	3	—	1	—	2	—	—	—	—	—	2	—	2	—
26	—	—	2	—	1	—	4	—	5	1	3	—	—	—	—	—	1	—	1	—	3	—	2	—
27	1	—	2	—	—	1	2	—	4	—	2	—	1	—	1	—	1	—	—	—	2	1	2	—
28	1	—	1	—	2	—	3	—	1	—	5	—	—	—	2	—	1	—	—	—	—	—	—	—
29	1	—	1	—	1	—	1	—	1	—	2	—	—	1	3	—	3	—	1	1	—	—	1	1
30	2	—	—	—	—	—	1	—	2	—	3	—	—	—	2	1	—	—	—	—	4	—	1	—
31	2	1	—	—	2	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—
N.D.	—	1	1	1	2	—	2	—	4	1	4	—	2	—	5	—	2	—	—	1	1	—	1	—
T.	34		3 39		1 30		3 55		5 64		5 66		2 49		7 48		5 46	—	35		5 40		1 37	1

In Fig. 5, the data from the column headed *T.* in Table 4—*i.e.*, the total numbers of the observed falls—are plotted against the hours of fall. The absolute maximum of the curve (47) occurs at 3 P.M., and the absolute minimum (0) exactly 12 hours earlier, at 3 A.M.[5] While the data from which Tables 4 and 5

TABLE 5

THE DISTRIBUTION OF OBSERVED FALLS BY HOURS

Hour	*A.*	*S.*	*T.*	Hour	*A.*	*S.*	*T.*
12 Midn.	5	1	6	1 P.M.	27	1	28
1 A.M.	4	1	5	2 P.M.	25	2	27
2 A.M.	6	—	6	3 P.M.	45	2	47
3 A.M.	—	—	—	4 P.M.	38	3	41
4 A.M.	5	1	6	5 P.M.	25	3	28
5 A.M.	11	—	11	6 P.M.	22	1	23
6 A.M.	8	—	8	7 P.M.	19	1	20
7 A.M.	20	1	21	8 P.M.	26	1	27
8 A.M	23	—	23	9 P.M.	14	3	17
9 A.M.	22	2	24	10 P.M.	10	1	11
10 A.M.	19	—	19	11 P.M.	13	—	13
11 A.M.	23	—	23				
12 Noon	34	1	35	Total	444	25	469

and their accompanying graphs have been assembled are naturally more numerous than were the statistics accessible to Farrington and Khan,[5] an analysis of our material leads to no conclusions concerning either the months or the hours of fall that differ radically from those of the forenamed investigators.

It is noteworthy that 152 falls (146 *A.* and 6 *S.*) of the 469 included in this study occurred between midnight and noon, while 317 (298 *A.* and 19 *S.*), or more than twice as many, took place between noon and midnight. It is, then, an indisputable fact that many more falls (over twice as many *A.* and 3 times as many *S.* and more than twice as many of both kinds together) have occurred between noon and midnight as have taken place between midnight and noon. It will be interesting to see how future data affect these ratios. That a human

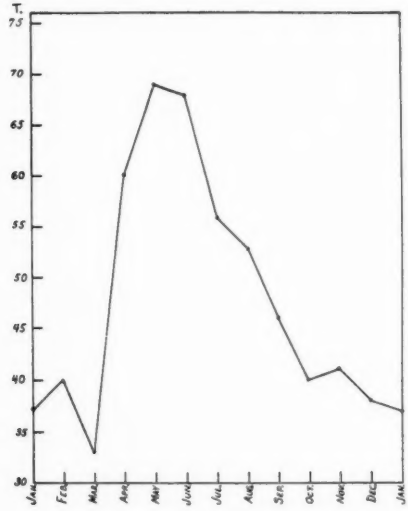


FIGURE 4
OBSERVED FALLS BY MONTHS

factor is strongly in operation here too is obvious, for the simple reason that many more potential observers of falling meteorites are active between 7 A.M. and 10 P.M. than between 10 P.M. and 7 A.M. Certain cosmic factors that probably have something to do with the phenomenon have been discussed by Farrington.[6]

Since 1833, not a single year has passed without the occurrence of at least one observed fall, the maximum number being 15 for 1933; since 1850, not a year has elapsed without the recovery of at least one unwitnessed fall, the maximum number being 38 for 1937; and since 1818, not a year has gone by without the record of at least one fall, observed or unobserved, the maximum number being 41 (of which only 3 were witnessed) for 1937. 1854 was the first year for which the total number of recorded falls (both *O* and *U*) was as high as 10; in 1863, the number was 15; in 1868, it was 17; in 1887, 22; in 1903, 23; in 1933, 24; in 1936, 29; and, finally, in 1937, it reached the "all-time high," to date, of 41! Since 1919 (except in 1940, for which the records are still incomplete), the number has

been never less than 10. The steady increase in meteoritical activity, especially since 1920, is well reflected in the data of Table 3 and Fig. 3.

It is informing to compare the average numbers of falls per annum for the single decade 1930-39, with the corresponding numbers for the entire 150-year interval from 1790 to 1939. The comparison is made most effectively by aid of

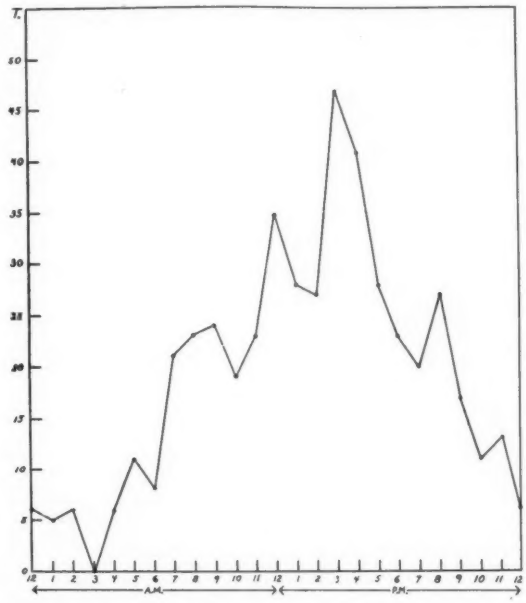


FIGURE 5
OBSERVED FALLS BY HOURS

the following tabulation, in which the first column (I) lists the intervals; the second (O), the *total* numbers of observed falls within them; the third ($\overline{O}$), the *average* numbers of observed falls *per year* in them; the fourth (U), the total numbers of unobserved falls; the fifth ($\overline{U}$), the average numbers of unobserved falls per annum; the sixth (T), the total numbers of falls of both varieties; and the seventh ($\overline{T}$), the average numbers of falls of both kinds per year.

I	O	$\overline{O}$	U	$\overline{U}$	T	$\overline{T}$
1790-1939	591	3.94	695	4.63	1286	8.57
1930-1939	72	7.2	157	15.7	229	22.9

NOTES

[1] Following are enumerated all the *authentic* falls of the world (21 in number) that antedate 1790. Of these, 13 (all *A.*) were observed and 8 (7 *Si.*; 1 *So.*) were unobserved.

(1) FALLS OBSERVED BEFORE 1790 (ALL *A.*)

1492: Ensisheim, Alsace, France
1520: Oliva-Gandia, Valencia, Spain
1698: Walkringen, Bern, Switzerland
1715: Schellin, Stargard, Pomerania, Prussia, Germany
1723: Ploschkovitz, Litomerice, Bohemia, Czechoslovakia
1741: Ogi, Hizen, Kyushu, Japan
1753: Tabor, Bohemia, Czechoslovakia
1753: Luponnas, Ain, France
1766: Albareto, Modena, Italy
1768: Lucé, Sarthe, France
1768: Mauerkirchen, Upper Austria
1773: Sena, Sariñena, Huesca, Spain
1785: Eichstädt, Middle Franconia, Bavaria, Germany

(2) UNOBSERVED FALLS RECOVERED BEFORE 1790

1600: Morito, Chihuahua, Mexico (*Si.*)
1716: Siratik, Upper Senegal, French West Africa (*Si.*)
1724: Steinbach, Erzgebirge, Saxony, Germany (*So.*)
Before 1776: Xiquipilco, State of Mexico, Mexico (*Si.*)
1780-83: Descubridora, Catorce, San Luis Potosi, Mexico (*Si.*)
1783: Otumpa, Gran Chaco Gualamba, Argentina (*Si.*)
1784: Bendegó, Bahia, Brazil (*Si.*)
1784: Sierra Blanca, Jimenez, Chihuahua, Mexico (*Si.*)

[2] For the purpose of this investigation, the "eastern hemisphere" (or "Old World") is defined as extending from longitude W. 20° to E. 180° and the "western hemisphere" (or "New World"), from W. 20° to W. 180°.

[3] *Cf.* Fig. 9, p. 39, and the discussion in Chap. 4, "Times of Fall," pp. 37-45, of O. C. Farrington's *Meteorites*, 1915.

[4] A fall reported to have occurred at the instant t is credited to the hour H if $H - 30^m < t \leq H + 30^m$; *e.g.*, a fall that took place at 3:30 P.M. is catalogued under 3 P.M., but one that occurred at 3:31 P.M. is registered under 4 P.M.

[5] *Cf.* Fig. 10, p. 42, and the discussion in Farrington, *l.c.*, *n.* (3), *ante*, and the "Comparison of Meteorite Falls during A.M. and P.M. Hours," with fig., by M. A. R. Khan, *C.S.R.M.*, **2**, No. 1, 5-8; *P. A.*, **46**, 51-4, 1938.

[6] *L.c.*, *n.* (3), *ante*, pp. 43-5, including Fig. 11, p. 43.

The Schertz, Guadalupe County, Texas, Meteorite Proved Identical with Canyon Diablo, Arizona*

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ABSTRACT

The Schertz, Guadalupe County, Texas, iron meteorite of 308 g., which has been listed in two catalogs of Texas meteorites, resembles a typical Canyon Diablo, Arizona, iron. An investigation at Schertz and at other points in south Texas revealed that a large shipment of iron meteorites from Canyon Diablo was sent there about 1893, and that subsequently all of these irons were abandoned or lost except one piece of some 175 lbs., now at Yorktown, Texas. The so-called Schertz iron is in all probability one of the samples of this shipment.

The Schertz, Guadalupe County, Texas, meteorite was first listed in a "Preliminary Check List of Texas Meteorites," prepared by the writer for the Bureau of Economic Geology of the University of Texas, and published in its Vol. 2, pp. 220-3, of *The Geology of Texas*, "Structural and Economic Geology," by E. H.

*Read at the Eighth Meeting.

Sellards and C. L. Baker (1934). The data for this entry, no. 38 in that list, "one iron, 308 g. The George F. Kunz collection of meteorites, now in possession of Ernest Weidhaas, New York," were supplied by Dr. Sellards, who had been in correspondence with Mr. Weidhaas.

It seems that most of the Kunz collection had been acquired by the United States National Museum, which had passed by a number of duplicate and minor pieces; these had been secured by Mr. Weidhaas, who was puzzled by the Kunz label acompanying this iron, reading "No. 33, Cut-Off, Guadaloupe Co., Texas." Any thought that the specimen had actually been cut off of a larger piece was dispelled by the fact that it was obviously a small, individual iron. Sellards recognized at once the variant spelling of *Guadalupe* County, and found finally that the present town of Schertz had formerly been named "Cut-Off"!

A few years thereafter the writer visited in New York and, through the courtesy of Mr. Weidhaas, was able to inspect this iron. Its general shape was that of a twisted piece with irregular and ragged edges; there was some travertine deposit on it, and a small, rusted area, where it had once been etched, indicated vaguely some schreibersite lamellae. It bore a red "33"—red numbers having been used by Kunz on apparently all of his meteorite specimens. Altogether, the iron did not seem at all unusual, and the writer felt that all its characteristics indicated that it might be a transplanted Canyon Diablo, Arizona, specimen.

When we acquired the entire Weidhaas collection in 1939, and the iron was examined more closely, the writer resolved to make a trip of investigation to the Schertz region, which is approximately 20 miles northeast of San Antonio, near Randolph Field. This trip was made in July, 1940, with Messrs. Walter J. C. Weiss and Sears Roach, whose help and interest are gratefully acknowledged. At Schertz we learned speedily from the postmaster, Mr. George J. Bolton, that the locality was known originally only as "Cibolo Pit," from gravel deposits on the river of that name, and had acquired the name "Cut-Off" when a creek that had previously drained through a slough some half mile away changed its course and "cut off" through the town! The name was changed in 1895, when William Schertz, a leading business man, gave the railroad a plot of land for a station, conditioned on its naming the stop after him.

Through Ferdinand Schertz, a younger brother of the late William Schertz, we learned quickly that a man named Haberle had sent several hundred pounds (perhaps 600?) of iron meteorites to Cut-Off by freight many years ago; that they were packed in well-constructed boxes made of 1-inch boards, and were held by the railroad agent for charges, as no one ever paid the freight on them. Haberle had reputedly found the meteorites somewhere to the west. Although Schertz had some recollection that they had come from Helotes, Bexar County (near San Antonio), we went on to Seguin, Texas, to consult the widow of Louis Haberle (daughter-in-law of the elder Haberle who had shipped the meteorites in), and here the fuller facts came to light.

The elder Haberle had worked for a railroad company, helping in construction work on tanks along the line to California. Mrs. Louis Haberle had married into the family in 1896, and her father-in-law had obtained the meteorites a few years earlier, probably in 1893 or 1894. They had come from some place where a number had been found, and Haberle had thought that they might be very valuable, but was unable to sell them to anybody in spite of repeated efforts. (It is certainly a fair inference that a sample sent out about this time is the piece that found its way into the Kunz collection.) All the larger pieces were allowed to lie around at the railway station, and some were later on moved into the cellar

of a store building since razed. While it was thought that there were 5 or 6 large pieces and an indefinite number of smaller ones, some of which were supposedly still on a vacant lot a few doors from the old railway station only a few years ago, a brief search and inquiry failed to bring any pieces to light. We propose to continue our activities along such lines in an endeavor to locate these lost specimens.

One piece was definitely traced, and tied very neatly into previous information we had. We had known for some time about a typical Canyon Diablo iron which is on exhibit in one corner of the floor of a saloon and domino hall at Yorktown, DeWitt County, Texas. The story there is that it comes from Arizona, and had been on exhibit at the "Little World's Fair" at New Braunfels, Texas, before being brought to Yorktown. Mrs. Haberle stated that she and her husband moved to Seguin from Schertz in 1915, and that a few years thereafter (1918?) her husband, coming home from San Antonio one day, decided to stop at Schertz and pick up one of the old, abandoned meteorites. He brought this specimen of some 175 pounds to Seguin, and, about 1925, one, Herman Sauermilch, got permission to exhibit it at the Little World's Fair at New Braunfels. Mrs. Haberle had more or less lost track of the piece since that time! There is every reason to believe that this is the specimen now at Yorktown.

This early acquisition of such irons is of interest, since the first public announcement of the finding of meteoritic irons near Canyon Diablo had been made only in 1891 (by A. E. Foote; see "The Meteor Crater of Canyon Diablo, Arizona: Its History, Origin, and Associated Meteoric Irons," by George P. Merrill, in *Smithsonian Misc. Coll.*, **50**, 478, 1908).

The listing of this meteorite as a separate fall has been repeated on p. 601 of the more comprehensive "Catalogue of Texas Meteorites," by Virgil E. Barnes, issued in 1940 as *Univ. of Texas Publ. No. 3945, Contr. to Geol.* It appears also as no. 164 in Addie D. Nininger's "Second Catalog of Meteoritic Falls Reported to the Society for Research on Meteorites," *C.S.R.M.*, **2**, No. 2, 100; *P. A.*, **47**, 213, 1939. This note has been prepared, not as a criticism of these listings, but to clarify the matter by preventing their erroneous continuation, and to record this shipment of Canyon Diablo irons that came to Texas so many years ago. It seems quite possible that more of them will "turn up" in the future, and the investigation here presented may prevent additional reports of false new irons from Guadalupe or near-by counties.

Notes from Amateurs

The New Haven Amateur Astronomical Society

At the October 4 meeting of the New Haven Amateur Astronomical Society Mrs. Everett Rademacher informed us of the History and Activities of the American Association of Variable Star Observers. She stated that the title of the A.A.V.S.O. is not strictly true. This society has members from all over the world. Although variable-star observing was the first and main activity, the interests have broadened to include other fields. Not all of the members are active observers. There is a place for others.

The A.A.V.S.O. was founded in 1911 by Wilson, Editor of POPULAR ASTRONOMY; Pickering, Director of Harvard College Observatory; and W. T. Olcott of Norwich. Wilson offered to publish the results of observations, Pickering to

provide headquarters and clerical workers, and Olcott was the first secretary. These and eight others formed the nucleus. The first method used for determining the magnitude of the variable was called the "step method" and required a comparison star of approximately the same magnitude as the variable. Pickering finally obtained charts of the variable fields with comparison stars marked with the magnitudes. It was then possible to ascribe a definite magnitude to the variable.

Now there are 200 members, and 500 variables under observation. One may observe any convenient variable on the list. Three-quarters of a million observations have been made to date. The Norwalk women learned mathematics from an engineer, reduced occultations, and the Committee on Occultations was formed. There is a Photographic Committee in charge of mapping ten areas of the sky. Mrs. Rademacher is associated with the nova search work. Sunspots have been adopted, and some aurora work is done. There is a large library, which welcomes bequests of books and telescopes. A slide collection has been formed, and there are quantities of data which are available to any one interested in statistical research. The dues are $2 a year, with a $1 initiation fee. The fall meeting is held at the Harvard Observatory, and the spring meeting is held at various observatories. The Association is eager to have new members, as the amount of observing abroad has fallen off since the war.

Mrs. Rademacher then showed a collection of slides of famous observers and the light curves of the important long-period and irregular variables. We also saw 800 feet of amateur movies of the more festive activities of the Association, made by Mr. Lewis Boss of North Scituate, Rhode Island.

To conclude the evening's activities, Mr. Welden Beacroft showed films he has taken of the Foucault shadow test, and Mr. Donald Kimball exhibited one of his oil paintings of an aurora and photographs of the aurora of September 18.

DOROTHY JOHNSTONE, *Secretary*.
267 Willow Street, New Haven, Connecticut.

The New Haven Amateur Astronomical Society

At the November meeting of the New Haven Amateur Astronomical Society Dr. Lyman Spitzer, Jr., of the Yale Observatory staff, spoke to us on the Origin of the Solar System. Had he spoken to us ten years ago he would have had a theory as to the origin of the solar system. Now we know less. Dr. Spitzer had arranged a series of balls about the room to show the scale of the solar system. The sizes of the planets had been magnified 100 times. The sun was the correct size in relation to the distances. He convinced us that the sun represented 99% of the mass of the system, and that the system was mostly empty space. Nevertheless there are one star, nine planets, 26 satellites, 2,000 to 15,000 asteroids, 1,000 to 100,000 comets and many billions of meteors to be accounted for. A surprisingly orderly pattern of planes of revolution and directions of rotation of both planets and satellites must be explained. Dr. Spitzer mentioned that Bode's law holds for most of the satellites in relation to their planets and for the planets in relation to any other planet, in addition to the more generally known relation of the distances of the planets from the sun. The universality of this geometric series suggests that hidden forces are at work.

Geologists, from changes in the atoms in the rocks, estimate that the age of the earth is two billion years. We assume that the whole solar system is of the same age and that the principles of physics were the same then as today. The question involved is how could the planets condense from gaseous material under

its own gravitational attraction. Gas in a small amount, as from a jet, dissipates into space. How much gas is needed for condensation?

The extra-galactic nebulae were once thought to be solar systems in the making. Since their distances were underestimated they were thought to be masses of rotating gases of the size of the solar system. A rotating mass of gas contracts as it cools, and matter at the periphery is thrown off by centrifugal force. The Laplace theory was once supported for a century, but was overthrown by the principle of the conservation of angular momentum. This states that the angular momentum of a body moving in a circle, defined by the product of the mass, the velocity, and the distance from the center of rotation, cannot change unless some force is acting. There is no celestial friction. A mass of gas would speed up as it contracted to form the sun and we would now be whizzing, for as the radius decreased the velocity must increase. Dr. Spitzer illustrated this point by standing on a rotating table, with books in each hand held at arm's length. As he pulled his arms in, his velocity increased, and when he stretched out his arms, he stopped.

The second theory advanced was the encounter or tidal theory. This accident theory has philosophical implications. In the entire galaxy we would be the most recent solar system. This theory presupposes that two stars approached at great velocities and fell towards each other at 1000 miles a second at the moment of closest approach. The debris of the collision, a mass of red-hot gas, condensed into planets with the same motion which the individual stars had. Each star was left with its own planets.

This theory accounts for the rotation of the planets, but not for any motion at right angles to the line of approach. The chief difficulty is how the planets would form from the gas debris. The gases would be too hot to condense and would explode rapidly in a few hours. We know that the pressure of the sun's atmosphere, or even of the earth's water, is tremendous. If we brought a volume of matter up from underneath the sun's atmosphere it would be hot and dense and tend to explode, even though matter at one million degrees radiates heat rapidly. Assuming a cyclindrical bridge of matter between the stars we can calculate that it doesn't cool rapidly enough to condense.

Littleton recently advanced the theory that the solar system originated from a binary star system which picked up dust from space. As the masses increased, the stars would spiral closer together until they finally touched in an elastic encounter and one would go shooting off into space. This is a modified form of the encounter theory and results in the same difficulty of planets condensing from a bridge of explosive matter.

Dr. Spitzer suggests that initially there were a sun and a disk of matter rotating around it; *i.e.*, the sun was not formed from the same cloud as the planets. As this nebula became flatter and flatter in the process of rotation it might condense into planets. This would explain why all the objects are in the same plane.

The Cleveland Astronomical Society

Although we have moved to new quarters in the fine auditorium of Warner & Swasey Observatory, we apparently could use still more room as our crowds continue to grow. Every seat was filled, with an overflow taking all available standing room at the lecture on October 24. The speaker was Dr. Robert R. McMath, of the McMath-Hulbert Observatory, pioneer in the field of motion pictures as applied to astronomy. His subject was "The Study of Solar Phenomena

by Means of Motion Pictures." It is impossible to say much about this lecture as the films must be seen in order to fully appreciate the progress that has been made and the valuable contribution to astronomy that has been accomplished. To actually see the cycle of a solar prominence from start to finish and the peculiar action of the gasses will furnish us with food for thought for a long time. Certainly we were looking at conditions with which we were not at all familiar here on the earth. Pictures of Mars were also shown and proved of much interest to those of us who have been watching the red planet this fall at its close approach. One film showed the McMath-Hulbert Observatory at Pontiac, Michigan, with many views of the original and high grade instruments used there. Much of the machine work is done right in their own machine shop by their own highly skilled staff. If you ever have the opportunity of seeing these films and hearing modest Dr. McMath lecture, it is well worth traveling many miles to be present. It is an event.

Dr. Nassau wishes to remind those in this vicinity that the class in Telescope Making under the direction of Mr. Russell meets at 6:30 P.M., the date of each regular meeting.

DON H. JOHNSTON.

Euclid Beach Park, Cleveland, Ohio.

The Norwalk Astronomical Society

The Norwalk Astronomical Society held its seventh annual dinner on October 25. The members of the Society have been active during the last seven years observing Variable Stars and Meteors. They have computed tables for Occultation reductions and made telescopes. A few have given illustrated talks at various Norwalk Clubs and schools.

The speakers at the dinner were Dr. and Mrs. John Pierce of Cambridge, Massachusetts, who told of their trip to South Africa to view the total eclipse of the sun on October 1, 1940. Dr. Pierce is a physicist at the Cruft Laboratory of Harvard University, who does research work in radio, especially on the effect of the ionosphere on radio waves. He described his observations made during the eclipse. Mrs. Pierce, formerly Catherine Stillman of the Vassar faculty, observed the eclipse from the astronomer's point of view. The talks were illustrated with slides and moving pictures. They also showed colored moving pictures of the country, where they stayed several months. Both lectures were greatly enjoyed by the members and by the guests who came from New York, New Haven, Waterbury, and Westport.

MARY C. HAMILTON, *Secretary.*

General Notes

Dr. Svien Rosseland, astrophysicist, formerly of the University of Oslo, has been appointed professor of astronomy at Princeton University, succeeding the late Dr. Raymond S. Dugan. (*Science,* October 24, 1941.)

Dr. Nicholas E. Wagman has been appointed acting director of the Allegheny Observatory, according to a recent announcement from the University of Pittsburgh. At the same time the appointment of Dr. Edwin G. Ebbighausen as astronomer and of Miss Esther M. Doody as assistant astronomer were also announced.

Dr. Seth B. Nicholson, astronomer in the Mount Wilson Observatory of the Carnegie Institution of Washington, delivered an Alexander F. Morrison Lecture of the Astronomical Society of the Pacific on the subject of "Sunspots and Magnetism" (illustrated) on the evening of Wednesday, October 29, 1941, at the University of California, Los Angeles.

The Rittenhouse Astronomical Society held its monthly meeting on Friday, November 14, 1941, in the Lecture Hall of The Franklin Institute. Dr. Wagner Schlesinger, director of the Fels Planetarium, explained the Planetarium, its construction and purpose.

The Astronomical Journal, after having been published at the Dudley Observatory during the past thirty-two years under the editorship of Dr. Lewis J. Boss and Dr. Benjamin Boss, has been transferred to the American Astronomical Society. It will be published under the auspices of that society with Dirk Brouwer, director of the Yale University Observatory, as editor. Communications concerning *The Astronomical Journal* should be addressed to *The Astronomical Journal*, Yale University Observatory, New Haven, Connecticut, U.S.A.

Sky and Telescope,—A new magazine bearing the name "Sky and Telescope" and representing a combination of "The Sky," formerly published at the Hayden Planetarium, and "Telescope," formerly published at Harvard College Observatory, appeared for the first time on October 25 of this year. It is published by Sky Publishing Corporation from Harvard College Observatory, under the editorship of Charles A. Federer, Jr., formerly editor of "The Sky." In addition Mr. Federer will assume duties as assistant to Dr. Harlow Shapley and a teaching fellow in Harvard University. Mrs. Helen Spence Federer, who is to be managing editor of "Sky and Telescope" has been appointed Pickering Memorial Assistant to Mr. Leon Campbell, Recorder of A.A.V.S.O.

Book Reviews

The Milky Way, by Bart J. Bok and Priscilla F. Bok. (The Blakiston Company, Philadelphia, Pa., $2.50.)

This is one of a series of nine books which constitute The Harvard Books on Astronomy, under the editorship of Dr. Harlow Shapley and Dr. Bart J. Bok. To begin with, it is to be noted that the books of this series furnish a striking example of the modern progress in the art of book-making from the mechanical point of view. The binding is in dark maroon colored fabricoid, which has been treated so as to be vermin-proof and water resisting. If necessary it can be cleaned with soap and water. The book paper is of a high grade of enamel coated paper, which permits the printing of illustrations in the text without loss of detail. The publishers are to be complimented upon presenting such an attractive series of volumes which will lend beauty and dignity to the library shelf.

In the 198 pages the authors have touched upon the recent work done upon the Galaxy by investigators the world over. A reading of the eleven chapters will give one a conception of our stellar system entirely different from that held by astronomers at the beginning of this century. Ideas as to its shape, extent, constituent parts, motion, the Sun's place in it, the space beyond, are brought

out clearly and supported by observational material. There are 96 illustrations, many of them celestial photographs made with the world's largest telescopes. In a pocket inside the back cover are two large-scale composite photographs, one of the Northern and the other of the Southern Milky Way.

The authors and the sponsor of this volume are such as to lend authenticity and dependability to it so that the reader may have the assurance that here, indeed, is the latest word regarding the structure of the stellar system of which we are a part. C.H.G.

Earth, Moon and Planets, by Fred L. Whipple; **Between the Planets,** by Fletcher G. Watson; **The Story of Variable Stars,** by Leon Campbell and Luigi Jacchia. Price $2.50 each.

These three volumes are part of the Harvard Books on Astronomy just published by the Blakiston Company of Philadelphia. The second of these supplements the first as it deals with asteroids, comets, meteors, and meteorites.

The books deal with their subjects in a simple manner and are truly popular in the accepted meaning of the term. Any intelligent person from the age of a high school student and upwards can read them with profit if only to acquire some knowledge in a field so generally neglected in American educational systems. They are also of value to the student of astronomy in that they bring together a great deal of material which is scattered through many volumes of observatory publications and astronomical periodicals. As supplementary reading for first year students in astronomy they are exceptionally valuable for the subjects are handled in an interesting manner, and the scientific imagination is stimulated. They are fully illustrated by reproductions of astronomical photographs as well as by many diagrams. When the series is completed it will prove to be a valuable addition to astronomical literature written by authors who know their subjects.

E.A.F.

Carleton College.

Meteorological Instruments, 206 pp., $3.25, and **Visibility in Meteorology,** 2nd edit., 136 pp., $2.50, both by W. E. K. Middleton, meteorologist in the Meteorological Service of Canada, have been recently issued by the University of Toronto Press. Both books are written for those interested in these subjects who wish a good general knowledge of them without being engulfed entirely in the mathematical theories which are involved. There is, however, a sufficient development of theory for a good working knowledge of instruments or problems. The volume on Instruments has many references to original papers and books in the foot-notes while that on Visibility has an extensive bibliography of 342 titles in the appendix. Chapter headings in the volume on Instruments are as follows: 1. Propertes of Meteorological Instruments; 2. The Measurement of Atmospheric Pressure; 3. The Measurement of Temperature in Meteorology; 4. The Measurement of Atmospheric Humidity; 5. The Measurement of Precipitation and Evaporation; 6. The Measurement of Wind near the Surface; 7. The Measurement of Upper Winds by means of Pilot Balloons; 8. Instruments for Investigating Clouds; 9. Sunshine Records; 10. Instruments for Investigation of the Upper Air.

The chapter headings in the volume on Visibility are: 1. Introduction; 2. Behavior of Light in the Atmosphere; 3. The Appearance of Objects seen through the Lower Atmosphere; 4. The Appearance of Light Sources seen through the Lower Atmosphere; 5. Applications to the Calculation of the Visual Range; 6. Experimental Researches Relating to Visual Range and Visibility; 7. Instruments

for the Measurement of Visual Range; 8. The Visual Range in Practice; 9. The Dependence of Visual Range on the other Meteorological Elements; 10. Forcasting the Visual Range.

These books should prove to be of value to teachers and students of meteorology as well as to meteorological observers and pilots of air planes.

E.A.F.

Carleton College.

Linguistic Analysis of Mathematics, by Arthur F. Bentley, XII + 315 pp. $3.00. (The Principia Press, Inc., Bloomington, Indiana.)

Man's ideas about his world are constantly changing towards an ever-widening consciousness of the structure of things. Complementary to this growth is an increasing self-consciousness of the rôle that human minds play in the very analysis of that structure. The consequent philosophical study of "mind" has given rise to the familiar paradoxes of realism-idealism, solipsism, generalization, etc.

Perhaps the most promising direction in which this selfconsciousness is now moving is along that path which suggests, as Mr. Bentley puts it (p. 293), that these problems be transferred "from the mental to the linguistic base." It has been only within the past twenty years that language itself has been recognized as a conditioning part of man's environment. Investigation on this level has now been consolidated to such an extent that it may be identified as "semantics," the study of what words are, how they are used, and how they ought to be used. In this branch of modern science is Mr. Bentley's book to be classified: a field which is generally regarded as peripheral to the other sciences, but is already giving promise of becoming central.

The various symbol systems which comprise mathematics have attained their perfection by means of a fully self-conscious use of the language involved: in other words, by the postulational method. With such a technique full consistency (or "perfection") is acquired within the system itself. Ever since Euclid's first great system was postulated, however, men have been raising the question, What is the relation of such a system to other similar systems, and in general, to knowledge, fact, and experience? Here lie the so-called "foundation" problems in respect to which Mr. Bentley offers an approach which he calls "semantic analysis," or the extension of mathematical analysis to those symbol areas where it is not usually applied. That the title of the book might be reversed to read "Mathematical Analysis of Language" may suggest where its emphasis lies.

As Mr. Bentley sees them, such "foundation" problems may best be examined as linguistic problems involving the words and word-clusters in terms of which analysis is attempted, and in which the language of mathematics proper is embedded. Among these are such words and their implicates as "character", "number", "symbol", "real", and in particular, "thing" and "operation." After outlining his postulational approach in Part I, Mr. Bentley brings his technique to bear on these two latter words as a case study in Part II.

In those problems where a relationship is sought among the various branches of mathematics or between mathematics and other knowledge, his conclusion is that distinctions between the words "thing" and "operation" are entirely relative. They are mirrored in the story of the two workmen on the cathedral dome, one inside and one out. The first insisted that the dome was concave, while the other held that it was convex. Semantic analysis reveals that the matter of attaining consistency in the use of these terms rests upon the departure, which is open to selection

according to If-Then procedure. Within any system one may start from any postulated "thing" and proceed to name other "operations" in relation to this. Thus no correspondence is assumed between the symbol "thing" and whatever it is that the symbol is used to represent, in the sense of an x to X relationship. Rather, correspondence is investigated between the symbol "thing" and other symbols such as "operation", in a system of x to x relationship, with the goal of reaching full semantic consistency.

The significance of this essay, to use the author's own words (p. 119), is to counteract the common tendency to believe that "there must be in some way more 'truth' or more 'import' in the words we use obscurely than in the words we use exactly." That is, instead of examining mathematics in terms of "reality", or "facts", or "thing", the author asks that the tables be turned, and that these *words* be examined by mathematical techniques.

Since the publication of the book in 1932, there has appeared what might be considered an answer to Mr. Bentley's proposal, although from entirely different constructions. Alfred Korzybski's *Science and Sanity*, also taking mathematics as the most satisfactory language man has devised, formulates a calculus of language-as-a-whole, a natural theory of semantic evaluation.[1] Mr. Bentley's book opens the way for such advanced work by indicating the nature of the problems as well as a possible method of attack.

[1] Alfred Korzybski, *Science and Sanity: An Introduction to Non-Aristotelian Systems and General Semantics*, Science Press Printing Co., Lancaster, Pa., 1933. Second Edition, 1941.

HUGH D. FARLEY.

Carleton College, November 13, 1941.

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